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AN EVALUATION OF THE PERFORMANCE OF
A NEW STORM TRACKING METHODOLOGY

by

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AN EVALUATION OF THE PERFORMANCE OF A
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ABSTRACT

This report contains the results of an exploratory statistical analysis to evaluate the performance of the Systematic Error Identification System (SEIS) and the Vortex Tracking Program (VTP), when tracking weather systems.

AN EVALUATION OF THE PERFORMANCE OF A NEW STORM TRACKING METHODOLOGY

1. Introduction

Weather forecasts made by the Fleet Numerical Oceanography Center (FNOC) are based on a numerical weather prediction model called the Naval Operational Global Atmospheric Prediction System (NOGAPS). Until 1983 the only available measures of model performance were of a global nature (aggregated over all the weather systems monitored), such as means, variances and root mean square errors. The operational field forecasters, on the other hand, prefer error statistics relevant at the synoptic level, i.e., measures pertaining to forecasts of individual storms and troughs. Such measures would enable these forecasters to provide better subjective forecasts at the regional level. In 1982, the Naval Environmental Prediction Research Facility (NEPRF) began the development of the Systematic Error Identification System (SEIS); the primary data reduction methodology within SEIS is the Vortex Tracking Program (VTP). In the VTP, an atmospheric low/high pressure system is mathematically represented as a generalized six parameter elliptic function. The six parameters correspond with the primary features of a storm, viz., the amplitude A, R the semi-major of the elliptic representation of the storm, ε the eccentricity or the ratio of the semi-major to the semi-minor, α the orientation of the ellipse and X_o, Y_o the coordinates of the center of the storm. The units of measurement are millibars (mb) for A, and degrees with respect to the North for α while R, X_o, Y_o are measured in terms of a 63x63 FNOC hemispheric grid units. For each valid storm, the VTP uses an iterated non-linear least squares scheme to estimate A, R, ε, α, X_o, Y_o within the sea level pressure field for the analysis at time t as well as for the associated 12, 24, 36, 48 and 60 hour forecasts produced by NOGAPS. The iteration scheme requires a set of initial guess values for the parameters to produce the estimates for the analysis field at time t. These estimates are in turn used as guess values to produce the 12 hour forecasts; the 12 hour parameter

forecasts are used to generate the 24 hour forecasts and so on. The estimated parameter values for the analysis field at time t are also used as the first guesses for the analysis field at t + 12 hours. The estimates for the analysis field are usually referred to as verification values. Corresponding to each set of forecasted parameter values there will be a verification set obtained using the current (for the forecasted time) sea level pressure data. The difference between a forecasted value and its verification value is called the forecast error. SEIS, thus, provides the capability to track individual weather systems (by tracking the movement of the elliptic representation) and also a means to measure and analyze the tracking errors.

The modified NOGAPS model has been running on a real time basis since mid 1983. During the life cycle of each valid storm, twice each day (at noon and at midnight GMT), the elliptic parameter estimates are produced for the analysis field and the associated 12, 24, 36, 48 and 60 hour forecast fields. References [1], [2] and [3] discuss the VTP and SEIS models in more detail.

The objective of this project is the exploratory statistical analysis of the forecast errors to assess the performance of the SEIS/VTP model. Data on 80 storms, covering the North Pacific Ocean Basin, observed during the period January-May 1984 has been used in this study. The results of the analysis are described in the following sections. Section 2 contains overall measures of performance of SEIS/VTP, primarily summary statistics of forecast errors pooled over all the 80 storms. Error statistics pertaining to the tracking of individual storms are presented in Section 3. Conclusions and topics for further research are discussed in Section 4.

2. Analysis of Forecast Errors

A forecast error is defined as the difference between a forecasted parameter value and its verification value; an absolute forecast error is the absolute value of a forecast error. For each of the five forecasting periods (12, 24, 36, 48 and 60 hours) the forecast and the absolute forecast errors were subjected to various statistical analyses. Tables 1 and 2 contain the means ($\bar{X}$) and standard deviations (S) for these errors.

TABLE 1

SUMMARY STATISTICS OF FORECAST ERRORS

Forecast Period	Number of Samples	A		ε		R		α		X_0		
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$
12	487	-1.53	5.20	-0.05	1.49	0.21	1.27	4.75	49.83	-0.06	0.77	0.1
24	429	-2.67	6.69	-0.07	1.47	0.19	1.38	4.60	52.14	-0.08	1.01	0.1
36	371	-4.11	7.68	-0.13	1.86	0.27	1.73	4.83	56.10	-0.14	1.22	-0.
48	329	-5.14	8.50	-0.18	1.84	0.28	1.76	5.51	53.95	-0.11	1.34	-0.
60	288	-5.08	9.61	-0.30	2.03	0.21	1.85	5.10	50.85	-0.09	1.45	-0.

TABLE 2

SUMMARY STATISTICS OF ABSOLUTE FORECAST ERRORS

Forecast Period	Number of Samples	A		ε		R		α		X_0		
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$
12	487	3.87	3.79	0.85	1.23	0.85	0.98	28.79	40.93	0.50	0.59	0.5
24	429	5.56	4.57	0.92	1.15	1.00	0.98	32.65	40.89	0.69	0.73	0.7
36	371	6.84	5.39	1.07	1.52	1.19	1.28	37.26	42.18	0.87	0.86	1.0
48	329	7.65	6.32	1.07	1.51	1.19	1.32	36.65	39.92	0.97	0.93	1.2
60	288	8.38	6.92	1.20	1.67	1.20	1.42	35.20	36.99	1.04	1.01	1.3

The following general conclusions appear warranted. The NOGAPS forecasting methodology does forecast the parameters A, R, ε, X_o, Y_o quite well. With regards to the forecasting of the orientation α, although the mean errors are not excessive, the standard deviations are somewhat high. In many cases the forecast errors are negative indicating a negative bias, i.e., the forecasted values tend to be on the low side of the verification values. With a few exceptions, the means and standard deviations increase with an increase in the forecasting period; this is to be expected in view of the higher levels of uncertainty involved.

The autocorrelations for lags 1 to 5 between the forecast errors are presented in Table 3. Except for the lag-one autocorrelations of about .30 for the forecast errors of A, X_o, Y_o the rest of the autocorrelations are quite negligible. This implies that a large error in forecasting a parameter at a given time will not have a lasting effect on future forecast errors. Also, the correlation matrices (correlations between the errors in forecasting A, α, R, ε, X_o, Y_o) in Table 4 show that these correlations are negligible with one exception -- the correlation between the errors in forecasting R and ε is around .5. This may be interpreted to mean (with the one exception) that a large forecast error for one parameter will not have a detrimental effect on the estimates of the other parameters.

In an attempt to model the statistical behavior, gamma distribution were fit to the 12, 24, 36 and 48 hour absolute forecast errors. The histograms with the fitted gamma distribution superimposed are in Figures 1-18. Gamma distributions appear to serve as good statistical models of the absolute forecast errors for A and R. In the other cases, the lack of fit may be attributed to a higher peakedness in the data; a Weibull distribution may provide a better fit. Although no graphs are presented, gamma distributions did not provide a good fit to the forecast errors (appropriately translated/shifted to make them positive) also. Further work will be necessary to determine the most appropriate statistical distributions to model the probabilistic behavior of the forecast errors. Proper statistical modeling of the error data could be useful for exploring the development of uncertainty contours (confidence regions) for the movements of weather systems.

TABLE 3

AUTOCORRELATIONS BETWEEN THE FORECAST ERRORS

Parameters	12 Hr Forecasts Lag 1	2	3	4	5	24 Hr Forecasts Lag 1	2	3	4	5
A	.13	.04	-.05	-.02	.04	.33	.11	-.06	-.09	-.10
ε	.04	.07	-.10	-.01	-.01	.14	-.12	-.06	.03	-.01
R	.02	.10	.08	.05	0	.21	0	.03	.08	-.05
α	-.05	-.01	-.05	-.01	.02	-.04	.03	0	-.07	.02
X_o	.05	.05	0	-.04	-.06	.25	.05	-.07	-.01	-.03
Y_o	.22	.11	.10	-.02	-.07	.28	.08	-.02	.04	.07

Parameters	36 Hr Forecasts Lag 1	2	3	4	5	48 Hr Forecasts Lag 1	2	3	4	5	60 Hr Forecasts Lag 1	2	3	4	5
A	.35	.02	-.07	-.05	-.05	.31	-.04	-.04	-.03	-.07	.28	.02	.01	.01	-.02
ε	.04	0	-.01	-.06	0	.14	-.07	-.02	-.04	-.01	.16	-.03	.07	.11	.05
R	.29	.06	0	.03	.02	.31	.03	.03	-.03	-.05	.18	-.03	0	-.03	.04
α	-.03	.04	-.02	.03	-.02	-.06	.04	.01	.06	.04	.10	.06	.05	.02	-.08
X_o	.34	.06	.03	-.05	-.05	.41	.07	-.05	-.04	-.03	.29	.07	-.05	-.02	0
Y_o	.29	.11	.08	0	.06	.36	.06	0	-.04	.07	.36	.06	.02	-.09	-.09

TABLE 4

CORRELATION MATRICES FOR FORECAST ERRORS

Para-meters	12 Hr Forecasts A	ε	R	α	X_o	Y_o	24 Hr Forecasts A	ε	R	α	X_o	Y_o
A	1	.08	-.03	.09	.14	.02	1	.18	.07	.07	.10	.03
ε	.08	1	.48	.11	.06	-.08	.18	1	.55	.02	.15	0
R	-.03	.48	1	.09	-.19	.01	.07	.55	1	-.04	-.13	.05
α	.09	.11	.09	1	.04	0	.07	.02	-.04	1	.01	-.01
X_o	.14	.06	-.19	.04	1	-.11	.10	.15	-.13	.01	1	-.22
Y_o	.02	-.08	.01	.00	-.11	1	.03	0	.05	.01	-.22	1

Para-meters	36 Hr Forecasts A	ε	R	α	X_o	Y_o	48 Hr Forecasts A	ε	R	α	X_o	Y_o	60 Hr Forecasts A	ε	R	α	X_o
A	1	.10	0	-.10	.04	.10	1	.23	.03	.04	-.04	.15	1	.19	.01	.15	-.04
ε	.10	1	.48	.02	.17	-.05	.23	1	.54	.04	.12	.05	.19	1	.57	.05	.08
R	0	.48	1	-.04	-.11	.07	.03	.54	1	0	-.09	.12	.01	.57	1	-.05	-.05
α	.10	.02	-.05	1	-.04	-.08	.04	.04	0	1	-.02	-.10	.15	.05	-.05	1	.05
X_o	.04	.17	-.11	-.04	1	-.20	-.04	.12	-.09	-.02	1	-.22	-.04	.08	-.05	.05	1
Y_o	.10	.05	.07	-.08	-.20	1	.15	.05	.12	-.10	.22	1	.12	-.08	-.06	-.15	-.16

3. Statistics of Individual Weather Systems

To evaluate the performances of SEIS, in tracking individual weather systems, and the NOGAPS model in forecasting weather systems, data on 20 storms with at least 10 records per storm (i.e., 10 sets of forecasted and verification values per storm) were examined. The means $(\bar{X})$ and standard deviations (S) of the forecast errors for these 20 storms are in Table 5.

The trends in the forecast errors are similar to the global trends observed in the previous section; with the exception of the forecasting of α, the forecast errors are very small even at the individual storm level. The iterated non-linear least square procedure in VTP requires initial guess values for each of the parameters A, ε, R, α, X_o, Y_o; the initial guess for α is always specified as zero. We conjecture that this may be the cause of the somewhat erratic forecasts of α. A better initial guess, closer to the true value, may result in a better forecast of α. The SEIS/VTP appears to be exceptionally good in forecasting the center of a storm.

For each of the 20 storms the forecasted values of A, X_o and Y_o were plotted against their respective verification values. In several cases, the scatter plots indicated an approximate linear relationship between the forecasted and verification values. A few of these scatter plots are shown in Figures 19-30. A linear regression analysis was, therefore, performed with the forecasted value as the independent variable and the verification value as the dependent variable. The least squares estimates of the intercept and slope of the fitted line and also the estimated coefficient of correlation (a measure of goodness of the fitted line) are in Table 6.

TABLE 5

SUMMARY STATISTICS OF FORECAST ERRORS FOR INDIVIDUAL STORMS

orm nber	Number of Records	A		ε		R		α		x_o		x_o	
		$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s	$\bar{x}$	s
1	19	-9.9	5.2	0.6	1.3	0.8	1.5	4.4	99.0	5.3	0.8	0.1	0.3
2	18	-10.3	5.1	0.5	1.2	0.7	1.5	4.0	101.7	0.1	0.8	-0.1	0.3
3	34	-1.2	4.9	-0.6	1.5	-0.3	1.9	9.3	24.5	-5.2	0.7	-1.1	1.4
4	18	-6.4	5.1	-0.7	2.8	0.5	2.8	-3.3	20.3	1.1	1.4	-0.8	1.3
5	60	-5.6	10.1	0.1	0.9	0.6	1.4	-5.0	35.5	0.4	1.1	-0.5	1.8
6	19	-1.8	3.9	-0.2	1.0	1.4	1.7	6.9	31.3	-1.7	1.3	3.2	1.8
7	27	1.3	3.9	0.1	0.4	0.5	0.9	34.9	32.5	0.1	0.8	-0.9	1.4
8	41	-8.0	9.3	-1.3	3.3	0.7	2.3	3.5	47.2	-0.7	1.3	0.7	1.4
9	25	-3.2	16.0	-2.6	4.0	-0.5	1.4	11.0	74.8	-1.1	1.6	0.5	0.8
0	26	4.8	7.2	-0.1	2.4	0.4	1.1	-13.4	86.2	0.8	1.6	-0.4	0.5
1	23	-6.5	12.8	0.4	0.6	0.7	1.6	9.3	55.5	0.1	1.3	0.0	0.5
2	13	0.4	5.5	1.5	2.3	0.2	0.7	-10.7	29.2	0.1	0.9	0.0	0.5
3	63	-2.4	8.3	-0.1	1.7	-0.3	1.1	-6.9	54.4	0.5	1.1	0.8	0.6
4	10	-11.6	9.6	-0.1	0.8	-0.8	1.1	22.1	66.6	1.0	1.0	-0.2	0.5
5	20	-0.7	6.8	0.9	1.4	0.9	2.1	-7.3	36.7	1.2	2.0	-0.9	2.0
6	27	-2.0	6.7	-1.1	1.2	-0.9	2.0	7.5	33.0	-0.1	1.3	0.1	1.2
7	13	-6.6	4.2	-0.3	0.7	-0.7	0.8	-17.6	17.2	0.0	0.5	0.3	0.5
8	95	-3.4	6.7	-0.2	1.1	0.2	1.5	12.9	52.0	0.2	1.1	0.9	2.2
9	72	-5.1	9.4	0.3	1.4	-0.1	1.1	-11.0	54.8	0.1	1.0	0.1	1.9
0	51	-3.8	6.5	-0.5	2.7	-1.3	2.9	-20.1	36.8	-0.4	0.5	0.7	0.7

TABLE 6

ESTIMATED REGRESSION PARAMETERS

Storm No.	A			X_o				Y_o	
	Intercept	Slope	Correlation	Intercept	Slope	Correlation	Intercept	Slope	Correlati
1	212.9	0.79	0.91	12.1	0.45	0.55	28.8	0.25	0.51
2	630.2	0.37	0.90	15.5	0.25	0.64	38.9	-0.05	0.45
3	984.9	0.003	0.00	2.7	0.84	0.92	22.9	0.29	0.3
4	495.8	0.50	0.37	20.9	0.09	0.16	23.9	0.09	0.1
5	732.7	0.26	0.33	11.3	0.35	0.70	13.1	0.62	0.8
6	962.7	0.04	0.05	11.3	0.45	0.14	-7.3	1.12	0.7
7	589.3	0.41	0.75	2.0	0.88	0.75	15.5	0.61	0.9
8	357.8	0.64	0.64	7.5	0.68	0.87	12.4	0.57	0.8
9	1066.7	-0.08	0.09	8.5	0.63	0.85	8.7	0.69	0.9
10	714.8	0.28	0.28	-0.7	0.99	0.82	15.1	0.46	0.4
11	626.6	0.37	0.29	25.9	-0.20	-0.29	4.6	0.88	0.8
12	143.1	0.86	0.47	6.1	0.73	0.80	6.8	0.75	0.8
13	745.0	0.25	0.47	2.0	0.87	0.86	-0.2	0.98	0.9
14	-133.0	1.14	0.33	-4.0	1.19	0.48	10.7	0.59	0.8
15	446.2	0.55	0.67	7.9	0.60	-0.03	8.8	0.75	-0.2
16	640.4	0.35	0.79	-1.6	1.07	0.80	-0.6	1.01	0.6
17	349.5	0.65	0.09	4.1	0.81	0.32	0.4	0.97	0.3
18	812.9	0.18	0.59	8.4	0.52	0.60	0.3	0.99	0.8
19	261.3	0.74	0.57	22.5	-0.02	0.95	30.1	-0.09	0.9
20	959.5	0.04	0.81	10.1	0.50	0.91	27.9	0.24	0.9

The regression analyses confirmed what was observed from the scatter plots, namely, a linear fit in many cases. If the functional relationship between the forecasted and verification values can be determined with good precision, corrective action can be taken to remove this source of systematic error in the forecasting scheme. However, the results in Table 6 do not lend themselves to the determination of the functional relationship. More data needs to be examined and different ways of stratifying the data such as by geographic regions and/or climatic seasons may prove to be profitable. Another possibility is to group the available records for a storm according to the forecast periods, i.e., all 12 hour forecasts as one group, all 24 hour forecasts as another group, etc. Of course, this scheme can only be applied to storms with large numbers of records. We tried this approach on 4 out of the 20 storms (storms 5, 13, 18 and 19, each with 60 or more records). The records for each storm were formed into five groups, one for each of the forecast periods and a separate regression analysis was performed for each group.

The estimated regression parameters in Table 7 reveal a much stronger linear relationship when the data is stratified according to the forecast period. Also, one can discern a definite pattern in the relationship between the forecasted and verification values of the storm's amplitude A. For the 12 hour forecasts, the relationship is linear with an intercept value of about 260 and slope .7; the intercept and slope values for the 48 hour forecasts are around 475 and .5 respectively. This is only an empirical observation and a more extensive study will be necessary to confirm this. Even though there is a strong correlation between the forecasted and verification values of X_o and Y_o, no pattern is evident in the estimates of the intercepts and slopes of the fitted lines. Another observation

that can be made from the correlations in Table 7 is that the 12 and 24 hour forecasts, and to a lesser extent the 36 hour forecasts correspond well with the verification values; the efficiency of the forecasting scheme appears to drop after the 36 hour forecasts.

TABLE 7

ESTIMATED REGRESSION PARAMETERS FOR INDIVIDUAL FORECAST PERIOD

m	Forecast Period	A			X_o			Y_o		
		Intercept	Slope	Correlation	Intercept	Slope	Correlation	Intercept	Slope	Correlation
	12	275.3	0.72	0.77	3.4	0.81	0.80	10.6	0.68	0.83
	24	476.2	0.52	0.72	7.4	0.56	0.78	6.0	0.83	0.96
	36	748.6	0.24	0.37	10.1	0.40	0.82	12.6	0.64	0.85
	48	1062.5	-0.08	-0.09	12.7	0.26	0.66	19.0	0.45	0.60
	60	1235.6	-0.25	-0.24	13.4	0.23	0.72	22.5	0.34	0.61
	12	454.6	0.54	0.55	-2.0	1.11	0.96	-0.1	0.99	0.99
	24	572.5	0.43	0.52	3.3	0.81	0.94	-0.1	0.98	0.99
	36	740.7	0.26	0.39	6.4	0.63	0.78	0.1	0.97	0.99
	48	751.3	0.25	0.54	4.4	0.78	0.80	-1.4	1.01	0.99
	60	762.9	0.27	0.74	-1.0	0.99	0.78	-1.0	0.99	0.99
	12	256.9	0.74	0.77	2.2	0.90	0.92	0.1	1.00	0.96
	24	489.0	0.50	0.49	3.7	0.81	0.81	2.8	0.93	0.93
	36	454.4	0.54	0.60	6.4	0.67	0.60	8.1	0.78	0.81
	48	616.6	0.37	0.45	14.9	0.25	0.22	14.8	0.57	0.66
	60	437.2	0.56	0.61	14.3	0.27	0.28	16.8	0.51	0.60
	12	277.6	0.72	0.92	0.8	0.96	0.99	-0.7	1.02	0.99
	24	488.8	0.51	0.78	-0.8	1.05	0.99	-2.3	1.06	0.99
	36	646.1	0.35	0.54	-1.6	1.08	0.96	-1.9	1.06	0.94
	48	701.0	0.30	0.50	-4.3	1.20	0.94	-1.2	1.04	0.91
	60	819.9	0.18	0.38	-3.9	1.17	0.89	3.5	0.90	0.86

4. Conclusions and Recommendations

This study has demonstrated that the NOGAPS model performs exceedingly well in forecasting five of the six parameters of the elliptic representation of a storm. The maximum mean absolute error in forecasting the amplitude A is 8.38 (Table 2) which is less than 1% of the verification values that range between 900 and 1,000; the maximum standard deviation of these errors in 6.92. Similar positive statements apply to the errors in forecasting ε, R, X_o, Y_o as can be seen from Tables 1 and 2 and the single high mode close to zero in the histograms (Figure's 1-18) of absolute errors.

The autocorrelations (Table 3) between the errors in successive forecasts of any of the six parameters indicate that these errors may, for all practical purposes, be treated as independent. Similarly, for each forecast period, the errors in forecasting the parameters A, ε, R, α, X_o, Y_o appear to be independent (Table 4). What this implies is that a large error in forecasting a parameter may not have a lasting effect on other forecasts nor will it have a carry over effect on forecasting the other parameters.

Even at the individual storm level, the mean forecast errors and their standard deviations are quite small; once again the exception is the parameter α. Scatter plots of the forecasted values versus the verification values indicated a linear relationship between the two sets, in several cases. Regression analyses to fit straight lines to the data confirmed this observation (Table 6 and Figures 19-30). When the data was stratified according to the forecasts period, e.g., all 12 hour forecasts are treated as one group, and a separate regression analysis performed for each group the lienar relationship was accentuated (Table 7).

The overall conclusion is that the incorporation of the SEIS and VTP methodology within the NOGAPS model has improved the storm tracking capability of NOGAPS and the elliptic representation of storms provides a good means of providing synoptic level error statistics to the field forecasters.

We propose the following topics for further study and research:

1. Determine the most appropriate probability distributions to describe the probabilistic behavior of the forecast errors. The indications are that the Weibull family may provide a good fit to the absolute error data.

2. Develop procedures to generate uncertainty contours/confidence regions around the forecasted elliptic representations of a storm based on the probability distributions of the forecast errors.

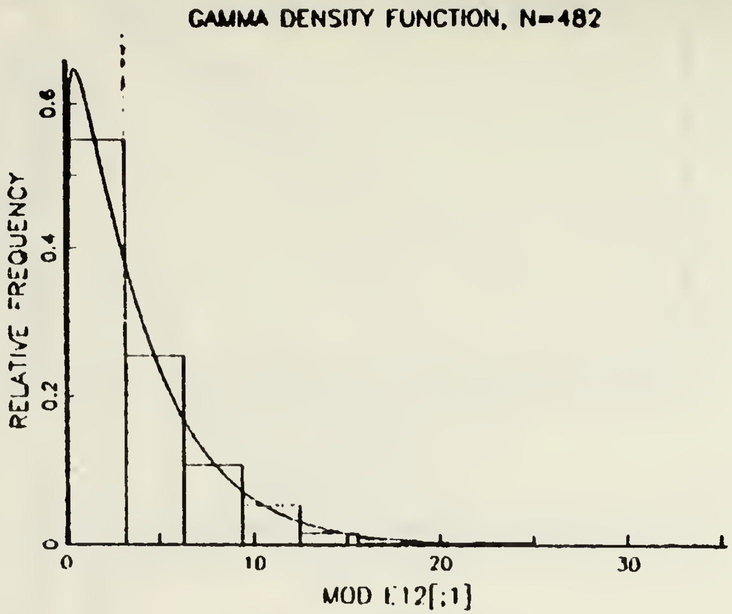
3. Examine more data to determine the functional relationship (if it exists) between the forecasted and verification values of the elliptic parameters. Different stratification schemes for the storm data such as by geographic regions and by climatic seasons could lead to the identification of sources of systematic errors and the means of remediation.

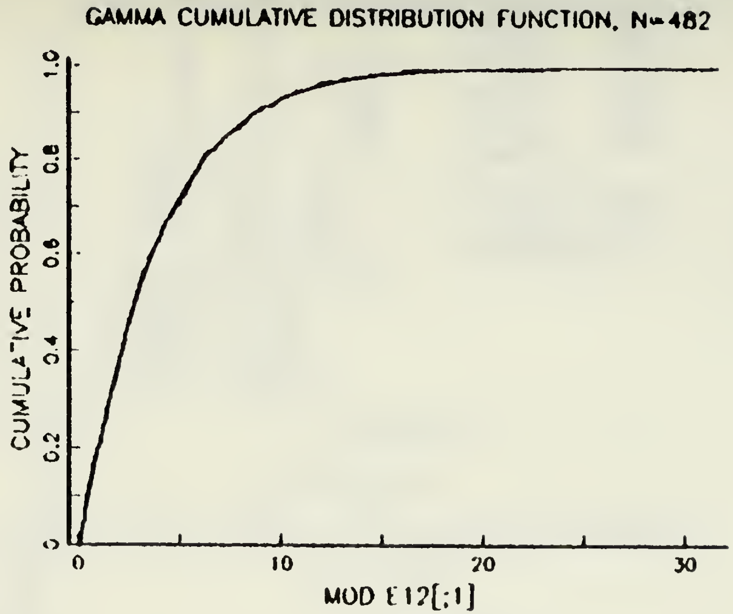
REFERENCES

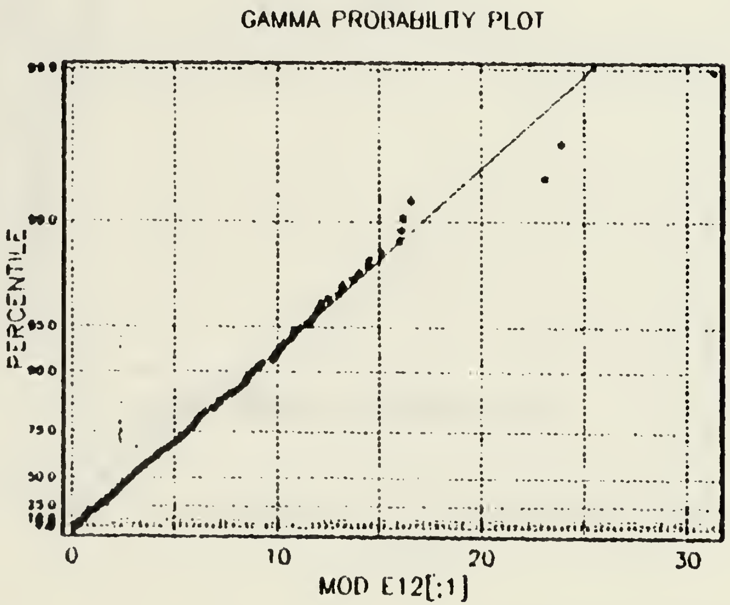
[1] Tsui, T. L. and Brody, L. R., "Objective Storm Tracking System", Preprint: Proceedings of the 9th Conference on Weather Forecasting & Analysis, Seattle, WA, June 28-July 1, 1982

[2] Harr, P. A., Brody, L. R. and Tsui, T. L., "Verification Statistics of the Naval Operational Global Atmospheric Prediction System Tailored For The Field Forecaster", Extended Abstracts: Sixth Conference on Numerical Weather Prediction, Omaha, NE, June 6-9, 1983.

[3] Harr, P. A., Tsui, T. L. and Brody, L. R., "Model Verification Statistics Tailored For The Field Forecaster", Preprints: 8th Conference on Probability and Statistics in Atmospheric Sciences, Hot Spring, Arkansas, 1983.







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LABEL	:	MOD E12[;1]
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MINIMUM	:	.100
MAXIMUM	:	31.200
CENSORING	:	NONE
EST. METHOD	:	MAXIMUM LIKELIHOOD

	SAMPLE	FITTED
MEAN :	3.9120	3.9120
STD DEV :	3.783	3.7050
SKEWNESS:	2.1835	1.8942
KURTOSIS:	11.208	8.3821

COVARIANCE MATRIX OF PARAMETER ESTIMATES

	ALPHA	BETA
ALPHA	0.0040874	-0.012853
BETA	-0.012853	0.083383

PERCENTILES	SAMPLE	FITTED
5.	0.3	0.23070
10.	0.4	0.40052
25.	1.3	1.2801
50.	2.8	2.8245
75.	5.3	5.4107
90.	8.7	8.7717
95.	11	11.282

GOODNESS OF FIT

CHI-SQUARE	:	1.7134
DEG FREED	:	4
SIGNIF	:	0.87300
KOLM-SMIRN	:	0.078362
SIGNIF	:	0.83293
CRAMER-V M	:	0.033564
SIGNIF	:	> .15
ANDER-DARL	:	0.35983
SIGNIF	:	> .15

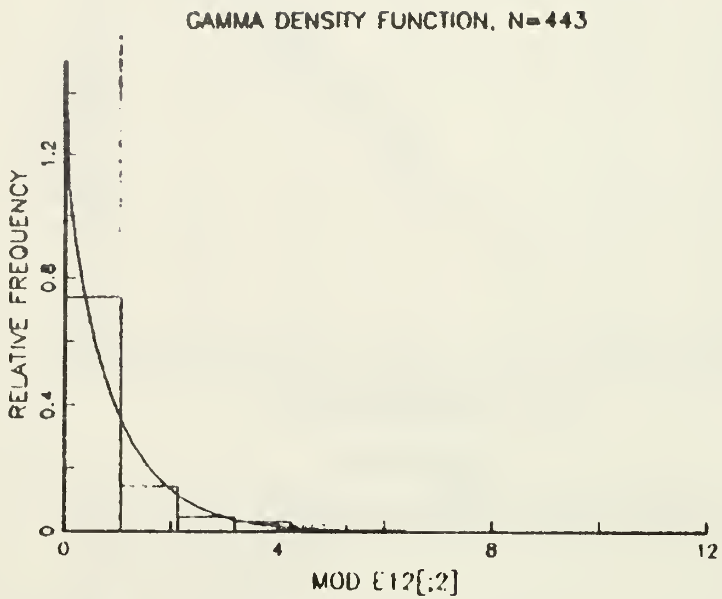
KS, AD, AND CV SIGNIF LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

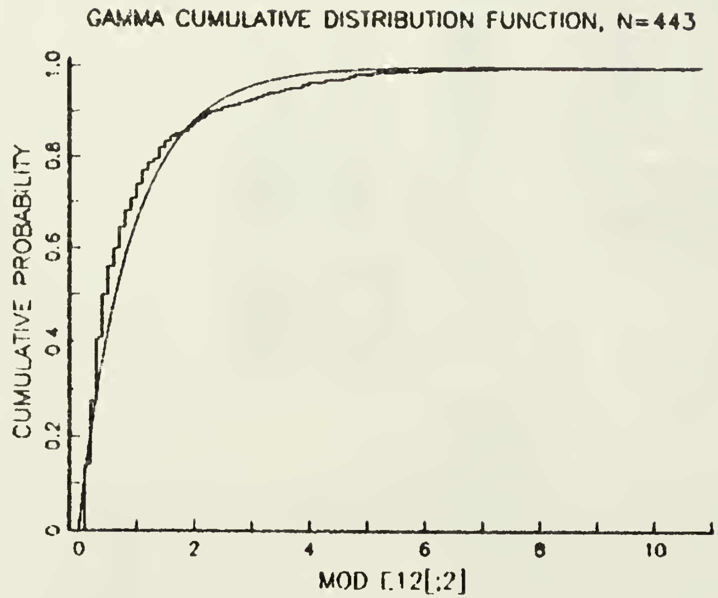
0.95 CONFIDENCE INTERVALS

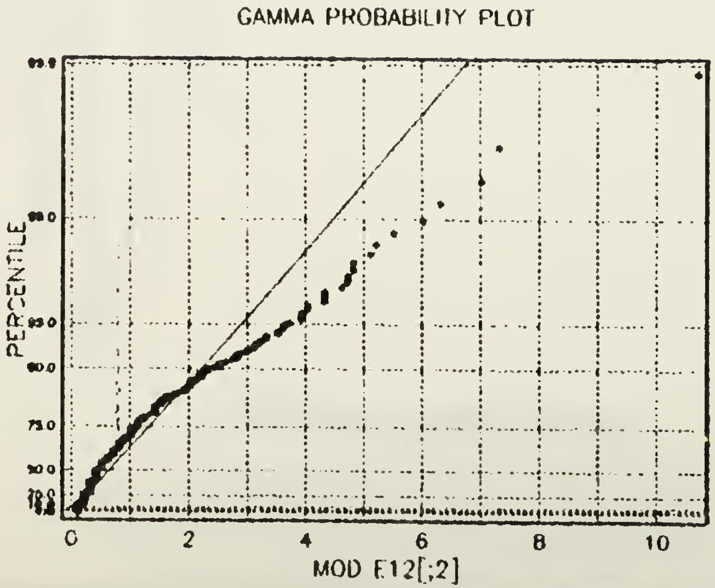
PARAMETER	ESTIMATE	LOWER	UPPER
ALPHA	1.1148	0.98930	1.2401
BETA	3.5090	3.0183	4.0035

Fig. 1

12-hour Absolute Forecast Errors for A







GAMMA DISTRIBUTION

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X           : MOD E12[;2]
SELECTION   : ALL
LABEL       : MOD E12[;2]
SAMPLE SIZE : 443
MINIMUM     :   .100
MAXIMUM     :  10.700
CENSORING   : NONE
EST METHOD  : MAXIMUM LIKELIHOOD

             SAMPLE    FITTED          COVARIANCE MATRIX OF
MEAN     :  0.93873   0.93873          PARAMETER ESTIMATES
STD DEV  :  1.2521    0.96585               ALPHA        BETA
SKEWNESS:   3.0328    2.0552         ALPHA  0.003113  -0.0032810
KURTOSIS.  15.055     9.3356          BETA -0.0032810  0.0057848

PERCENTILES SAMPLE    FITTED          GOODNESS OF FIT
     5:      0.1      0.041964        CHI-SQUARE :     2.03496E1
    10.      0.1      0.088301          DEG FREED:     7.00000E0
    25.      0.2      0.25338           SIGNIF   :     8.9207E-7
    50:      0.4      0.63703         KOLM-SMIRN :     1.4340E-1
    75:      1.1      1.3029            SIGNIF   :     2.4000E-8
    90:      2.3      2.193           CRAMER-V M :     2.05380E0
    95:      3.0      2.8701            SIGNIF   :    < .01
                                      ANDER-DARL :     1.10242E1
                                        SIGNIF   :    < .01
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

                  0.95 CONFIDENCE INTERVALS
PARAMETER   ESTIMATE   LOWER     UPPER
ALPHA       0.94703    0.83788   1.0564
 BETA       0.99220    0.84345   1.1411
```

Fig. 2

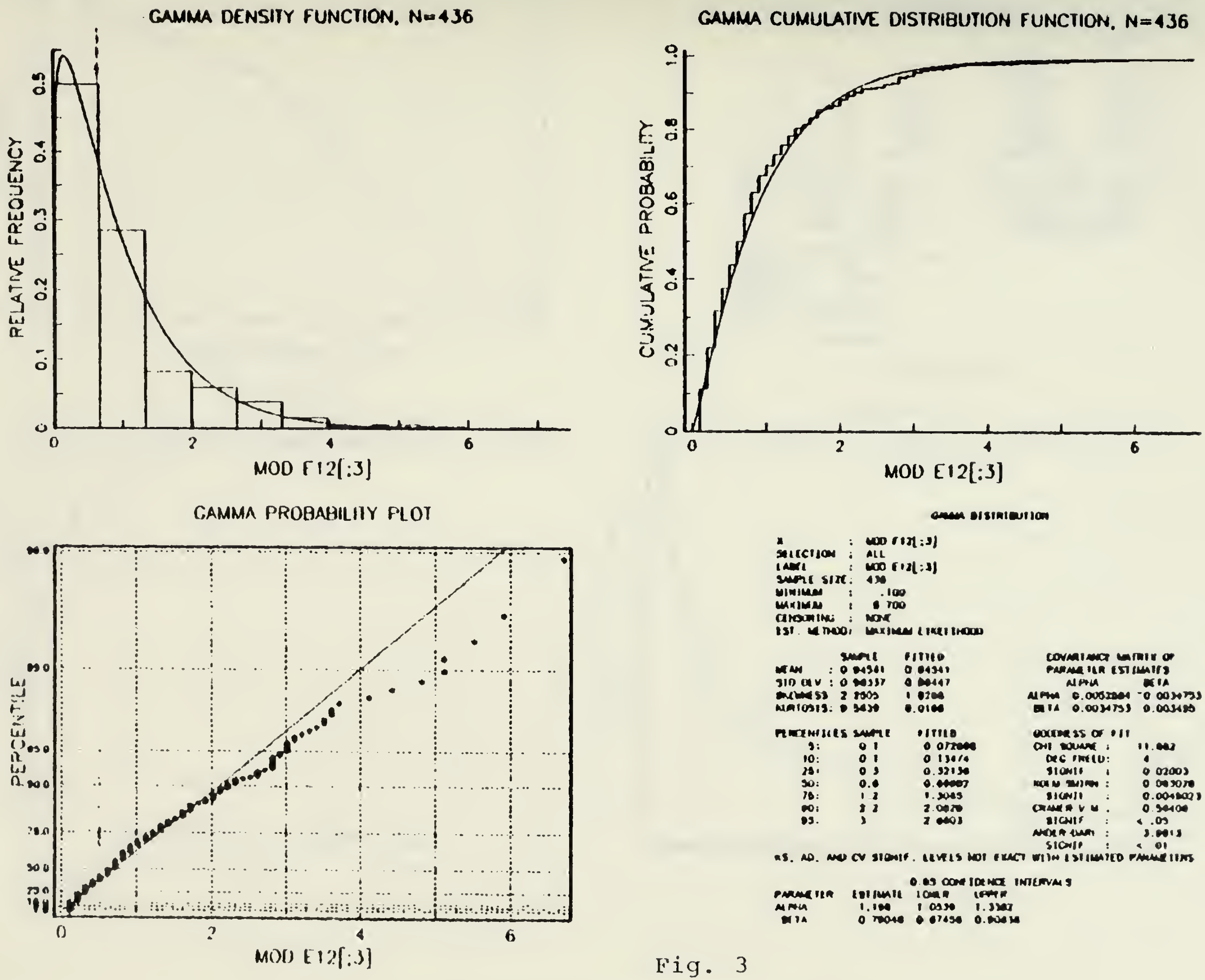
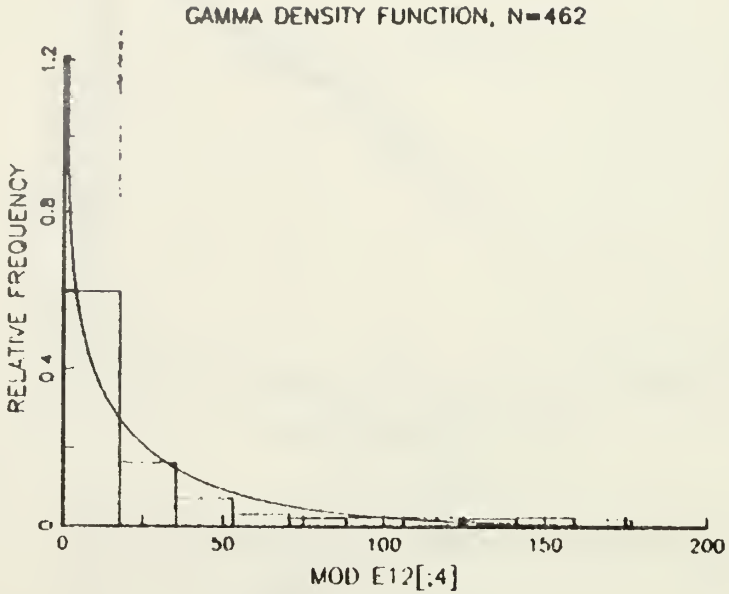
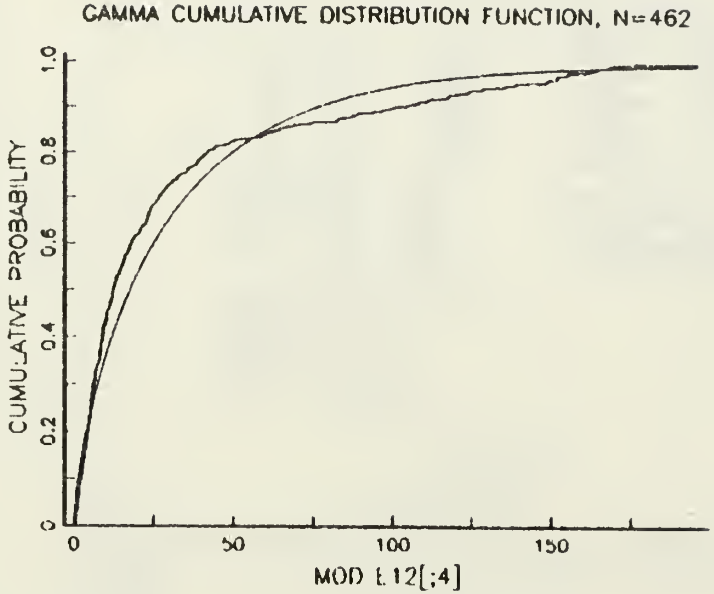
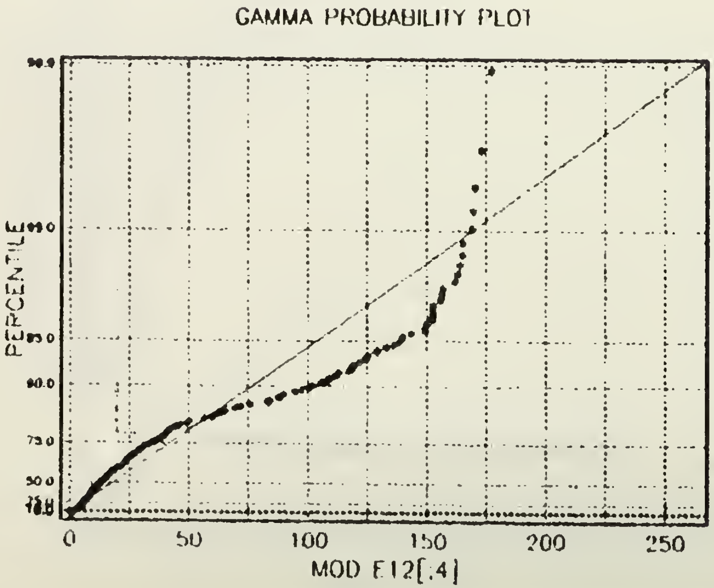


Fig. 3

12-hour Absolute Forecast Errors for R







GAMMA DISTRIBUTION

X : MOD E12[;4]
SELECTION : ALL
LABEL : MOD E12[;4]
SAMPLE SIZE : 462
MINIMUM : .100
MAXIMUM : 178.700
CENSORING : NONE
EST. METHOD : MAXIMUM LIKELIHOOD

	SAMPLE	FITTED
MEAN :	30.348	30.345
STD DEV :	41.413	36.318
SKEWNESS :	1.9813	2.3030
KURTOSIS :	5.8002	11.504

COVARIANCE MATRIX OF PARAMETER ESTIMATES

	ALPHA	BETA
ALPHA	0.0015322	¯0.096384
BETA	¯0.096384	11.798

PERCENTILES	SAMPLE	FITTED
5:	1.2	0.82771
10:	2.2	1.4348
25:	5.2	5.008
50:	12.3	17.038
75:	33.3	41.075
90:	100.3	78.22
95	137.8	103.39

GOODNESS OF FIT

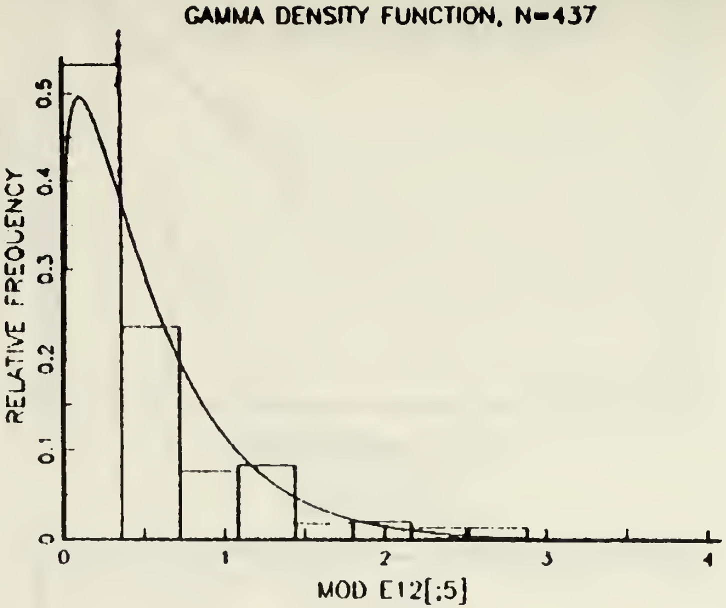
CHI-SQUARE	:	6.2057E1
DEG FREED	:	7.0000E0
SIGNIF	:	2.5137E¯10
KOLM-SMIRN	:	1.0191E¯1
SIGNIF	:	1.3804E¯4
CRAMER-V M	:	1.5411E0
SIGNIF	:	< .01
ANDER-DARL	:	8.5344E0
SIGNIF	:	< .01

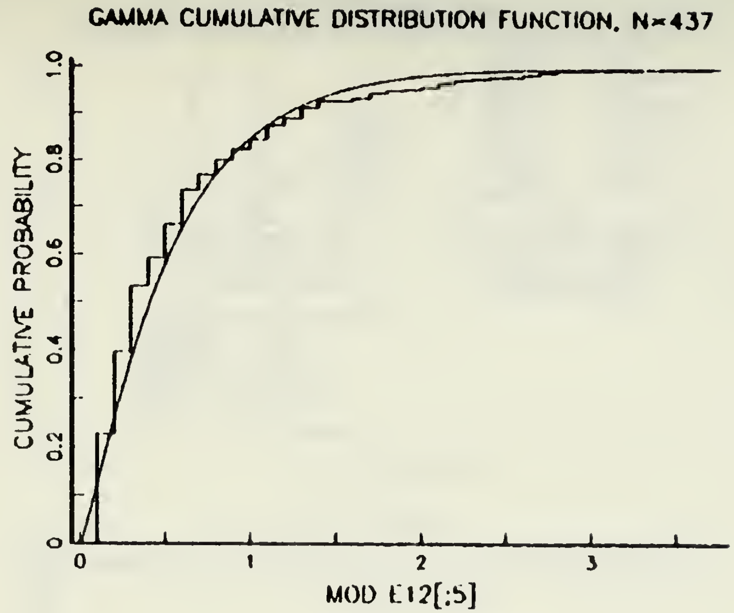
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

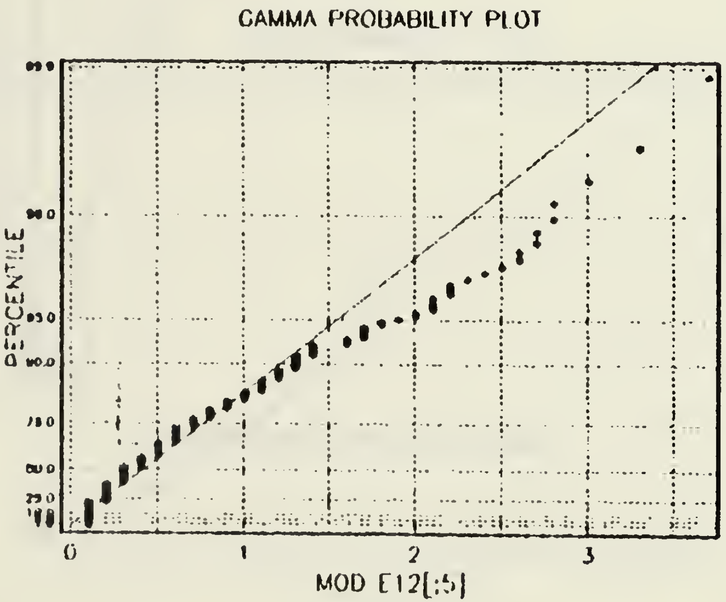
0.95 CONFIDENCE INTERVALS

PARAMETER	ESTIMATE	LOWER	UPPER
ALPHA	0.69875	0.62141	0.77400
BETA	43.405	38.737	50.199

Fig. 4







GAMMA DISTRIBUTION

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SELECTION   :  ALL
LABEL       :  MOD E12[;5]
SAMPLE SIZE :  437
MINIMUM     :   .100
MAXIMUM     :  3.700
CENSORING   :  NONE
EST METHOD  :  MAXIMUM LIKELIHOOD

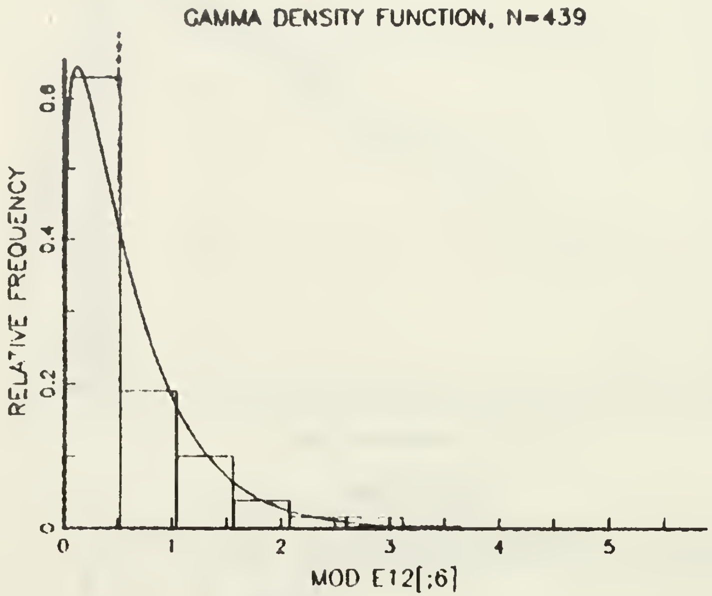
             SAMPLE    FITTED          COVARIANCE MATRIX OF
MEAN     :  0.534     0.534            PARAMETER ESTIMATES
STD DEV  :  0.50107   0.48094                ALPHA       BETA
SKEWNESS :  2.1044    1.8012       ALPHA  0.005804  -0.0020424
KURTOSIS :  8.2503    7.8685       BETA  -0.0020424  0.0011101

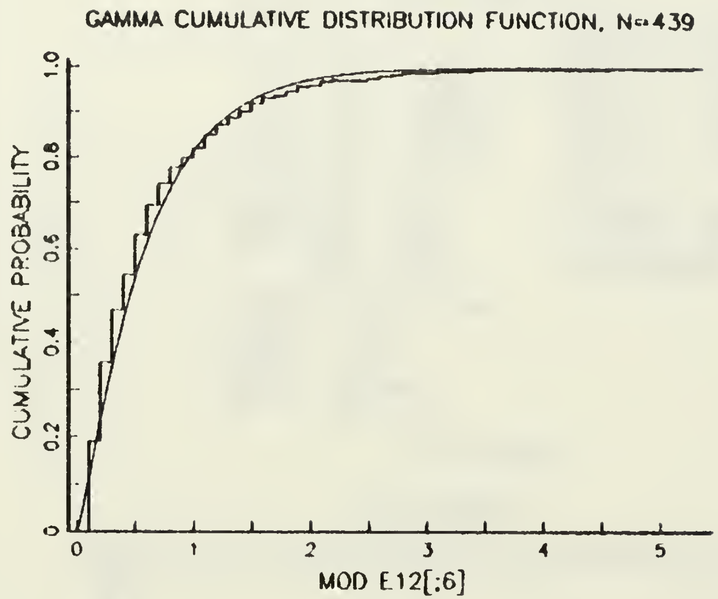
PERCENTILES SAMPLE    FITTED       GOODNESS OF FIT
      5:      0.1     0.045416     CHI-SQUARE  :   3.1280E1
     10:      0.1     0.082078       DEG FREED.:   4.0000E0
     25:      0.2     0.18318        SIGNIF    :   5.0735E-6
     50:      0.3     0.41548      KOLM SMIRN  :   1.8210E-1
     75:      0.7     0.76480        SIGNIF    :   3.3103E-9
     90:      1.3     1.2114       CRAMER V M  :   1.7187E0
     95:      1.8     1.5428         SIGNIF    :   < .01
                                   ANDER-DARL  :   1.1008E1
                                     SIGNIF    :   < .01
KS. AD. AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

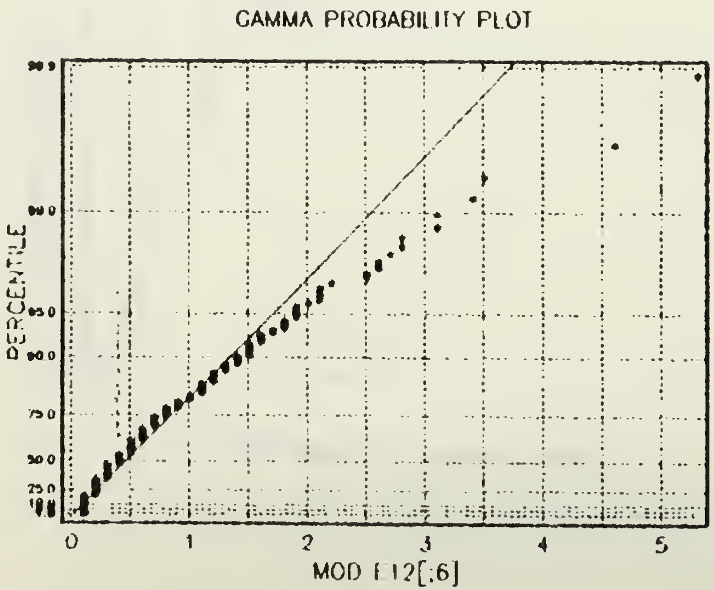
               0.90 CONFIDENCE INTERVALS
PARAMETER    ESTIMATE   LOWER     UPPER
ALPHA        1.2326     1.0862    1.3787
BETA         0.44034    0.38578   0.51403
```

Fig. 5

12-hour Absolute Forecast Errors for X_o







GAMMA DISTRIBUTION

X	:	MOD E12[;6]
SELECTION	:	ALL
LABEL	:	MOD E12[;6]
SAMPLE SIZE	:	439
MINIMUM	:	.100
MAXIMUM	:	5.300
CENSORING	:	NONE
EST. METHOD	:	MAXIMUM LIKELIHOOD

	SAMPLE	FITTED
MEAN :	0.61344	0.61344
STD DEV :	0.66427	0.55114
SKEWNESS:	2.6659	1.7999
KURTOSIS:	13.344	7.8431

COVARIANCE MATRIX OF PARAMETER ESTIMATES

	ALPHA	BETA
ALPHA	0.0056371	0.0027531
BETA	0.0027531	0.0013515

PERCENTILES	SAMPLE	FITTED
5:	0.1	0.050775
10:	0.1	0.092200
25:	0.2	0.21475
50:	0.4	0.45854
75:	0.8	0.84681
90:	1.4	1.3397
95:	1.8	1.7053

GOODNESS OF FIT

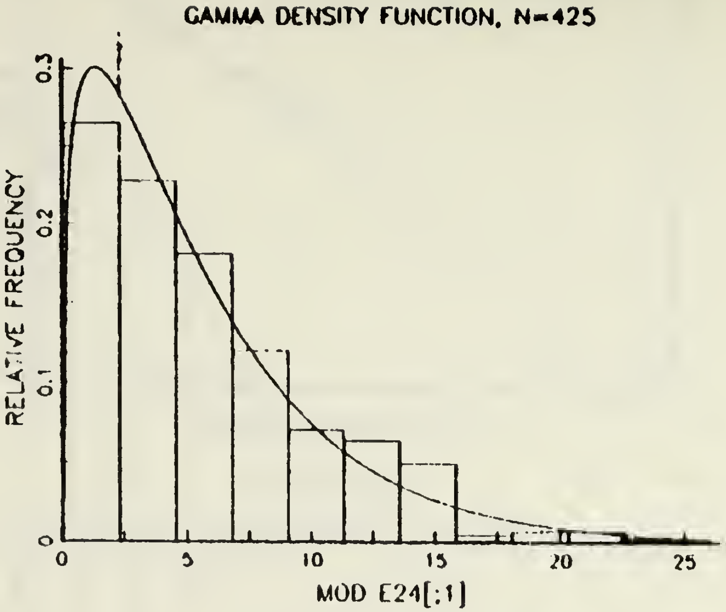
CHI-SQUARE	:	2.6346E1
DEG FREED	:	3.0000E0
SIGNIF	:	8.0540E-6
KOLM-SMIRN	:	1.2514E-1
SIGNIF	:	7.1370E-6
CRAMER-V M	:	1.2757E0
SIGNIF	:	< .01
ANDER-DARL	:	8.4112E0
SIGNIF	:	< .01

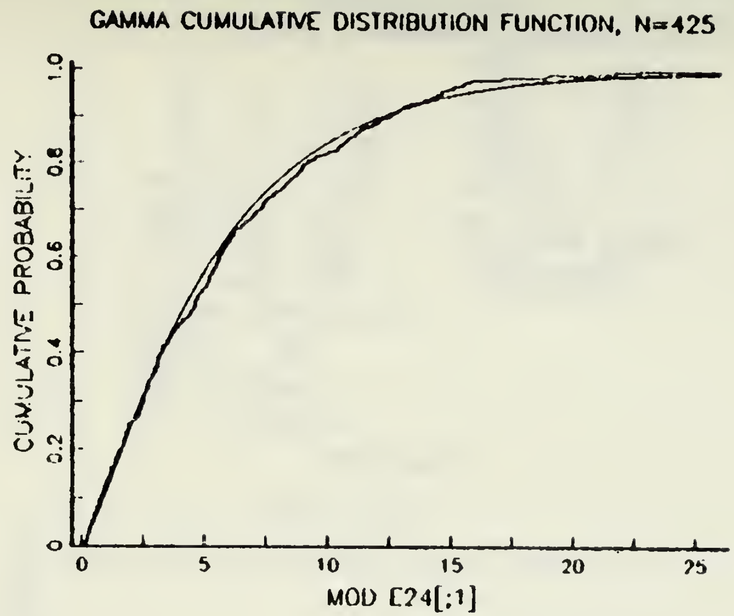
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

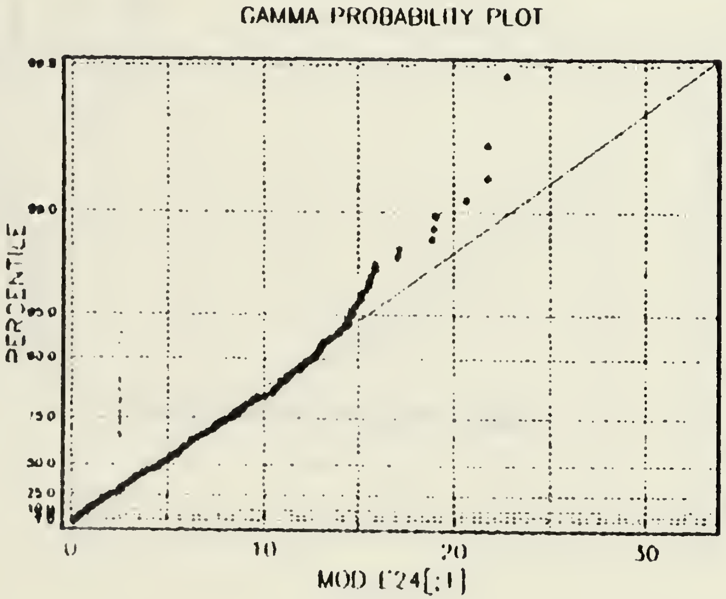
0.95 CONFIDENCE INTERVALS

PARAMETER	ESTIMATE	LOWER	UPPER
ALPHA	1.2309	1.0917	1.3661
BETA	0.49616	0.4231	0.56723

Fig. 6







GAMMA DISTRIBUTION

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X           :  MOD E24[;1]
SELECTION   :  ALL
LABEL       :  MOD E24[;1]
SAMPLE SIZE :  425
MINIMUM     :     .100
MAXIMUM     :   22.700
CENSORING   :  NONE
EST METHOD  :  MAXIMUM LIKELIHOOD

              SAMPLE    FITTED            COVARIANCE MATRIX OF
MEAN     :  5.0130    5.0130              PARAMETER ESTIMATES
STD DEV  :  4.5573    4.0501                 ALPHA        BETA
SKEWNESS :  1.0005    1.7035         ALPHA  0.0083158  -0.021433
KURTOSIS :  3.7440    7.005          BETA  -0.021433    0.10750

PERCENTILES SAMPLE     FITTED         GOODNESS OF FIT
     5.        0.4      0.50032       CHI-SQUARE  :   17.153
    10.        0.8      0.8912          DEG FREED :   7
    25         1.9      2.0257          SIGNIF    :   0.01844
    50         4.0      4.2443        KOLM SMIRN  :   0.039730
    75         8.2      7.7300          SIGNIF    :   0.51370
    90.       12.0     12.140         CRAMER V M  :   0.12500
    95        14.0     15.406           SIGNIF    :   > .10
                                      ANDER DARL  :   0.80707
                                        SIGNIF    :   > .15
KS, AD AND CV SIGNIF LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

               0.05 CONFIDENCE INTERVALS
PARAMETER   ESTIMATE   LOWER    UPPER
ALPHA        1.2802    1.1304   1.447
BETA         4.3840    3.7210   5.0070
```

Fig. 7

24-hour Absolute Forecast Errors for A

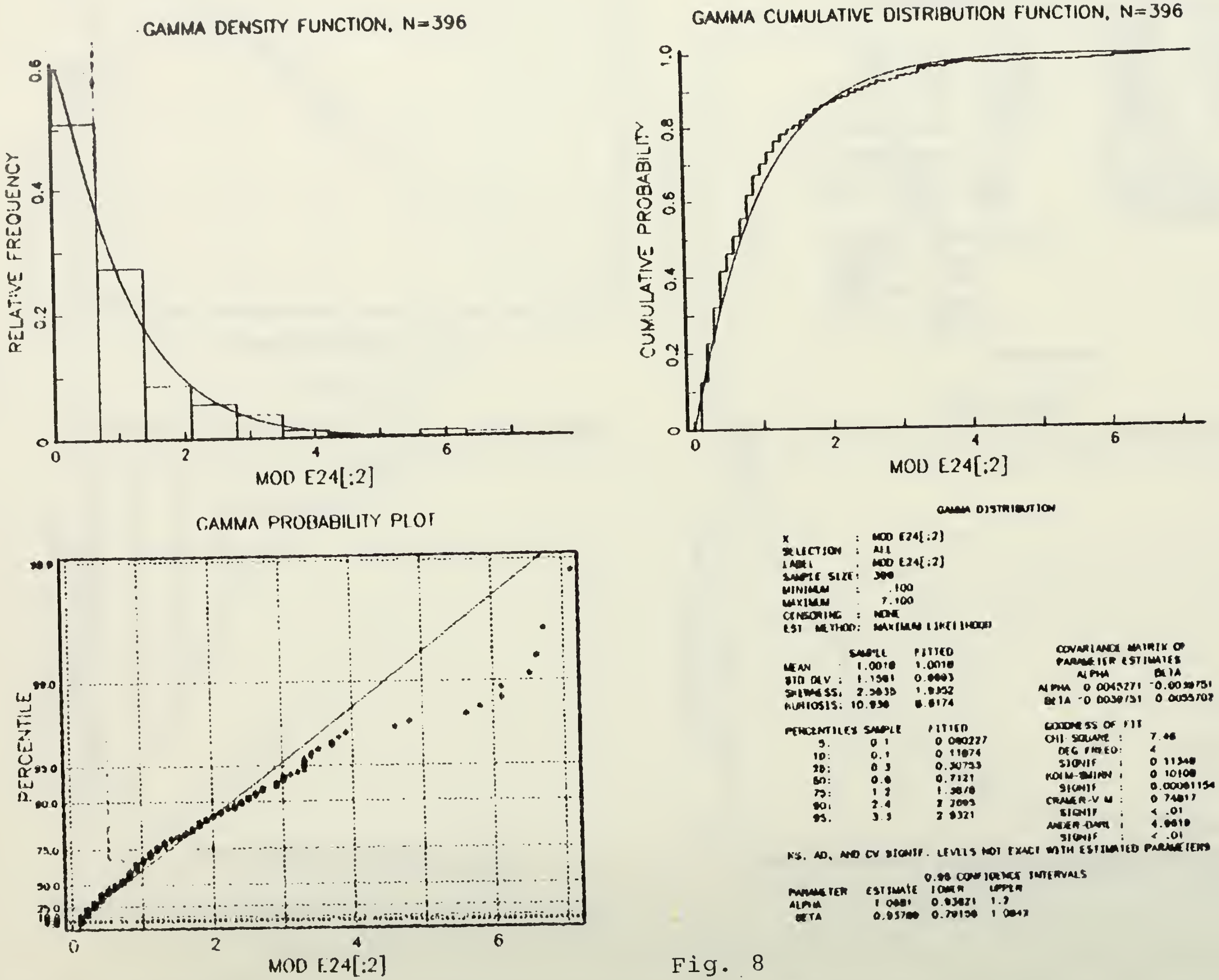

GAMMA DENSITY FUNCTION, N=396
RELATIVE FREQUENCY
MOD E24[:2]
GAMMA CUMULATIVE DISTRIBUTION FUNCTION, N=396
CUMULATIVE PROBABILITY
MOD E24[:2]
GAMMA PROBABILITY PLOT
PERCENTILE
MOD E24[:2]
GAMMA DISTRIBUTION
X : MOD E24[:2]
SELECTION : ALL
LABEL : MOD E24[:2]
SAMPLE SIZE: 396
MINIMUM : .100
MAXIMUM : 7.100
CENSORING : NONE
EST METHOD: MAXIMUM LIKELIHOOD
SAMPLE FITTED
MEAN : 1.0010 1.0010
STD DEV : 1.1501 0.9993
SKEWNESS: 2.3035 1.9352
KURTOSIS: 10.930 8.8174
PERCENTILES SAMPLE FITTED
5. 0.1 0.050227
10: 0.1 0.11074
25: 0.3 0.30733
50: 0.8 0.7121
75: 1.2 1.3870
90: 2.4 2.2005
95. 3.5 2.9321
COVARIANCE MATRIX OF PARAMETER ESTIMATES
ALPHA BETA
ALPHA 0.0045271 -0.0030751
BETA -0.0030751 0.0055702
GOODNESS OF FIT
CHI SQUARE : 7.46
DEG FREED: 4
SIGNIF : 0.11348
KOLM-SMIRN : 0.10108
SIGNIF : 0.00001154
CRAMER-V M : 0.74817
SIGNIF : < .01
ANDER-DARL : 4.8819
SIGNIF : < .01
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS
0.95 CONFIDENCE INTERVALS
PARAMETER ESTIMATE LOWER UPPER
ALPHA 1.0081 0.93821 1.2
BETA 0.95700 0.79150 1.0847

Fig. 8

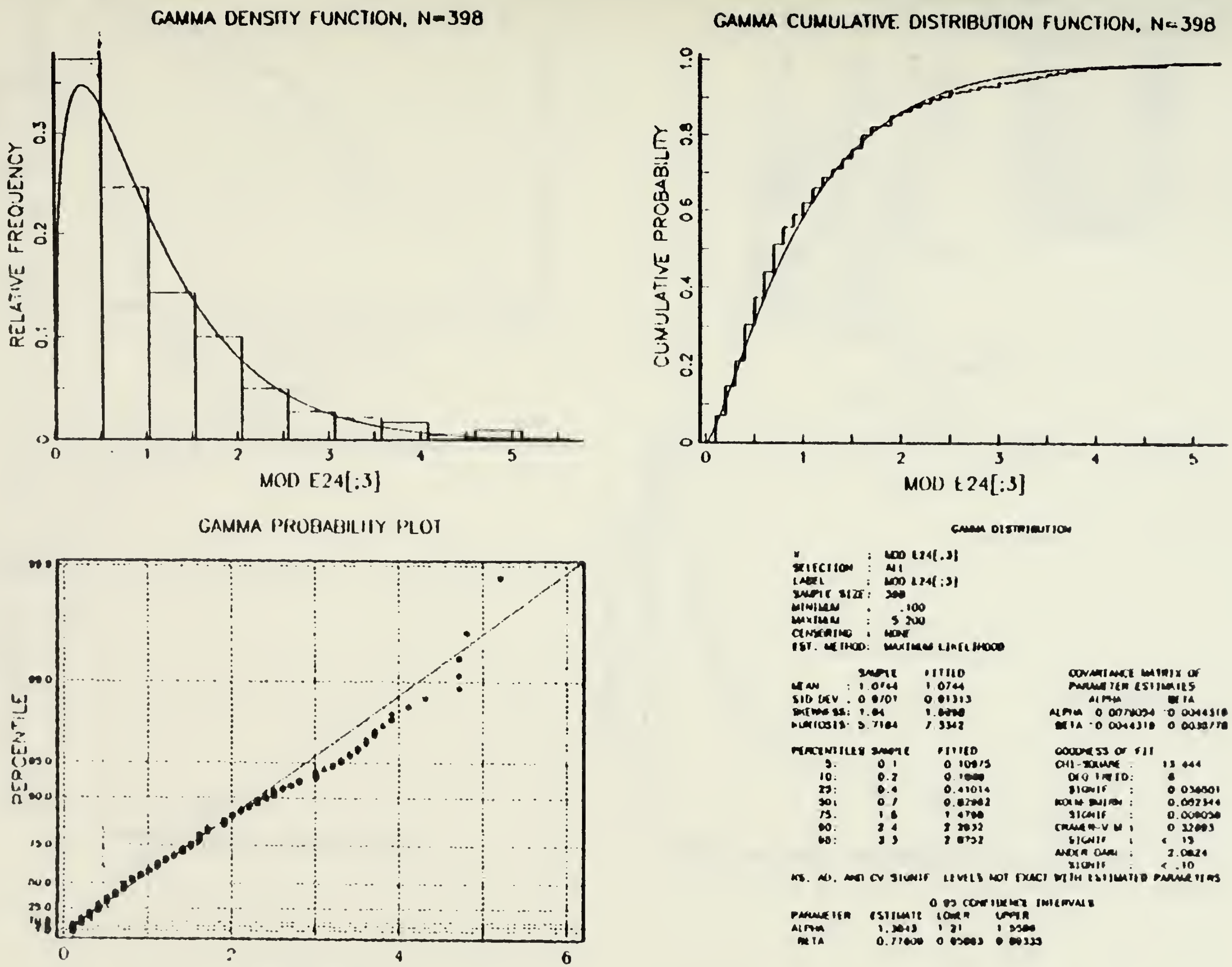
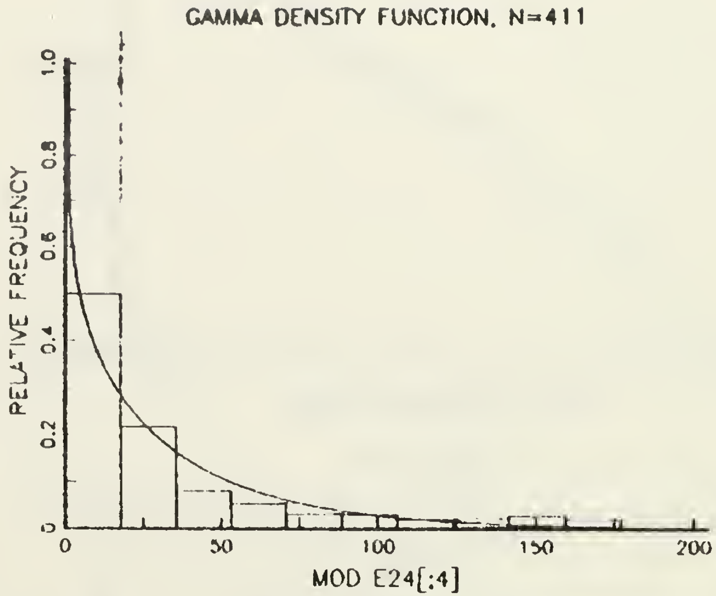
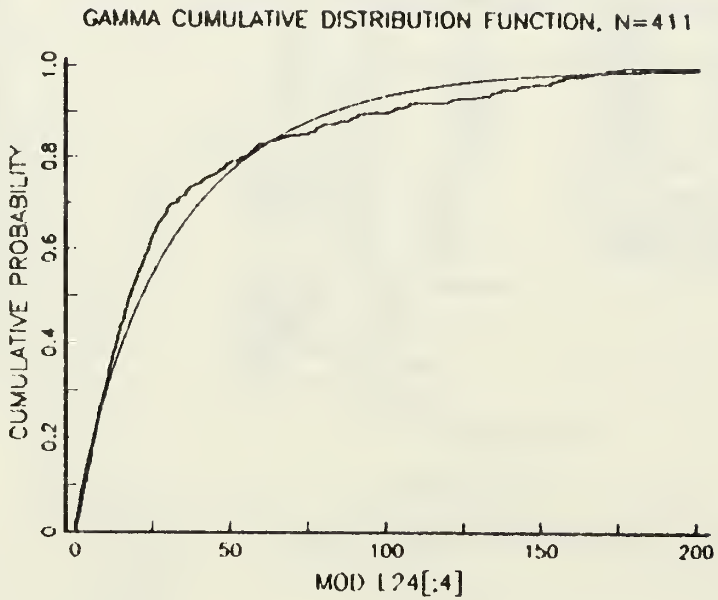
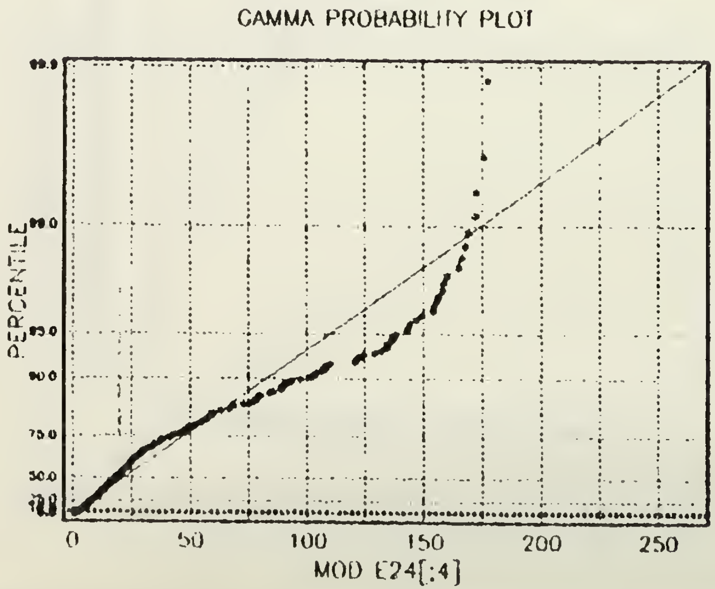


Fig. 9

24-hour Absolute Forecast Errors for R







GAMMA DISTRIBUTION

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SELECTION : ALL
LABEL : MOD E24[;4]
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MINIMUM : .100
MAXIMUM : 177.000
CENSORING : NONE
EST METHOD: MAXIMUM LIKELIHOOD

	SAMPLE	FITTED
MEAN :	34.078	34.078
STD DEV :	41.136	37.085
SKEWNESS:	1.8484	2.2106
KURTOSIS:	5.834	10.33

COVARIANCE MATRIX OF PARAMETER ESTIMATES

	ALPHA	BETA
ALPHA	0.0024307	-0.12400
BETA	-0.12400	11.489

PERCENTILES	SAMPLE	FITTED
5.	1.5	1.008
10.	3	2.3809
25	7.8	7.8189
50	17.8	21.004
75.	41.5	47.138
90.	96.8	82.401
95.	137.7	109.83

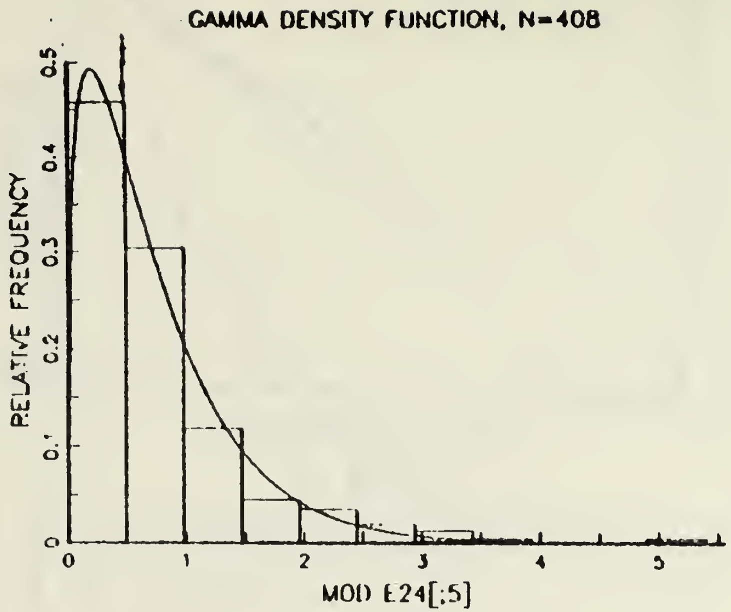
GOODNESS OF FIT
CHI-SQUARE : 3.902121
DEG FREED: 7.000000
SIGNIF : 3.1356E-6
KOLM-SMIRN : 8.6734E-2
SIGNIF : 3.3247E-3
CRAMER-V M : 7.3055E-1
SIGNIF : < .025
ANDER DARL : 3.992310
SIGNIF : < .01

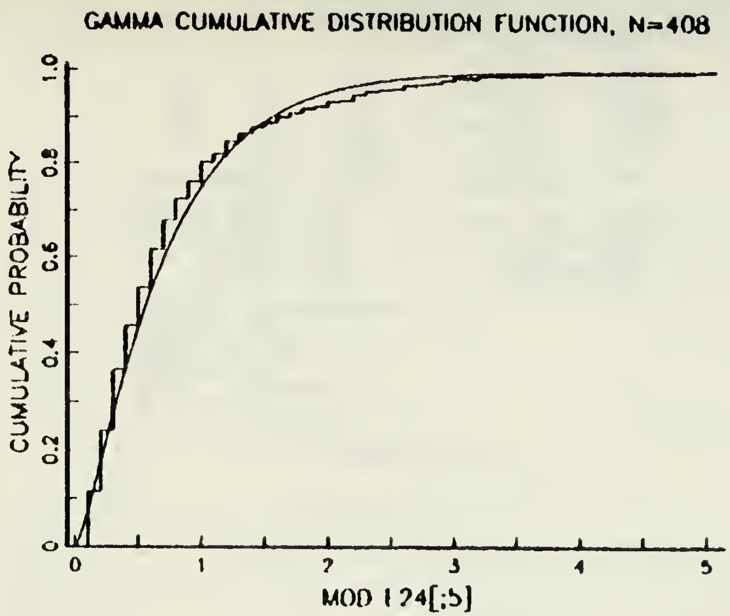
KS, AD AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

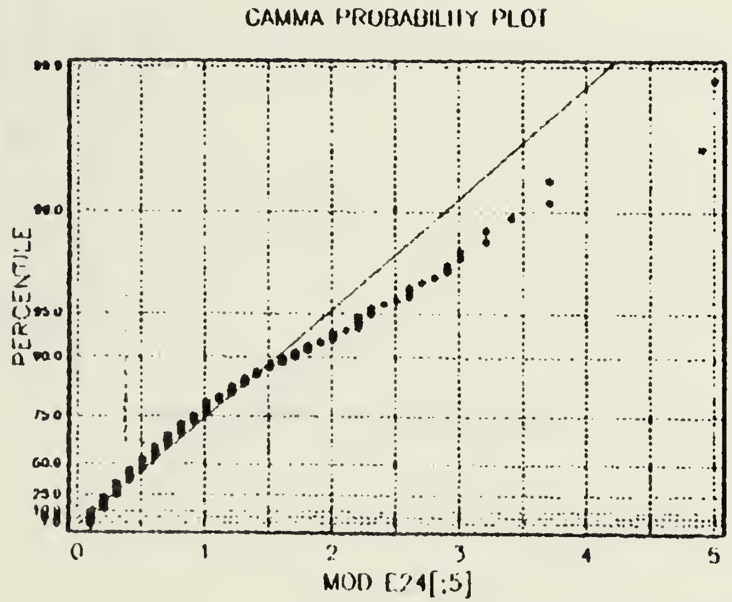
0.95 CONFIDENCE INTERVALS

PARAMETER	ESTIMATE	LOWER	UPPER
ALPHA	0.81851	0.72168	0.91534
BETA	41.631	34.994	48.269

Fig. 10







GAMMA DISTRIBUTION

X	:	MOD E24[;5]
SELECTION	:	ALL
LABEL	:	MOD E24[;5]
SAMPLE SIZE	:	408
MINIMUM	:	.100
MAXIMUM	:	5.000
CENSORING	:	NONE
EST. METHOD	:	MAXIMUM LIKELIHOOD

	SAMPLE	FITTED
MEAN :	0.73084	0.73084
STD DEV :	0.73770	0.62470
SKEWNESS:	2.3420	1.7009
KURTOSIS:	10.101	7.3403

COVARIANCE MATRIX OF PARAMETER ESTIMATES

	ALPHA	BETA
ALPHA	0.0073303	-0.0020350
BETA	-0.0020350	0.0018024

PERCENTILES	SAMPLE	FITTED
5.	0.1	0.073237
10:	0.1	0.1790
25:	0.3	0.27075
50:	0.5	0.58254
75:	0.9	1.0040
90.	1.7	[illegible]
95:	2.3	[illegible]

GOODNESS OF FIT

CHI-SQUARE	:	12.449
DEG FREED	:	4
SIGNIF	:	0.014301
KOLM-SMIRN	:	0.084087
SIGNIF	:	0.0012801
CRAMER-V M	:	0.74772
SIGNIF	:	< .01
ANDER-DARL	:	4.9047
SIGNIF	:	< .01

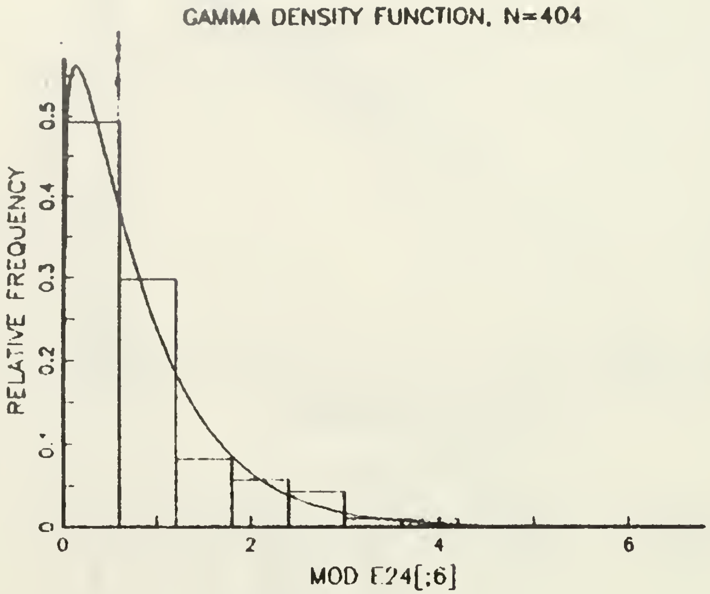
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

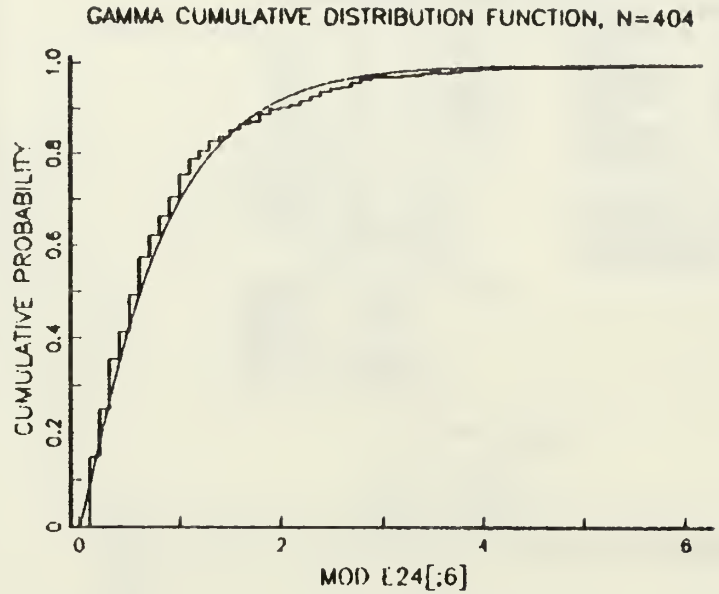
0.95 CONFIDENCE INTERVALS

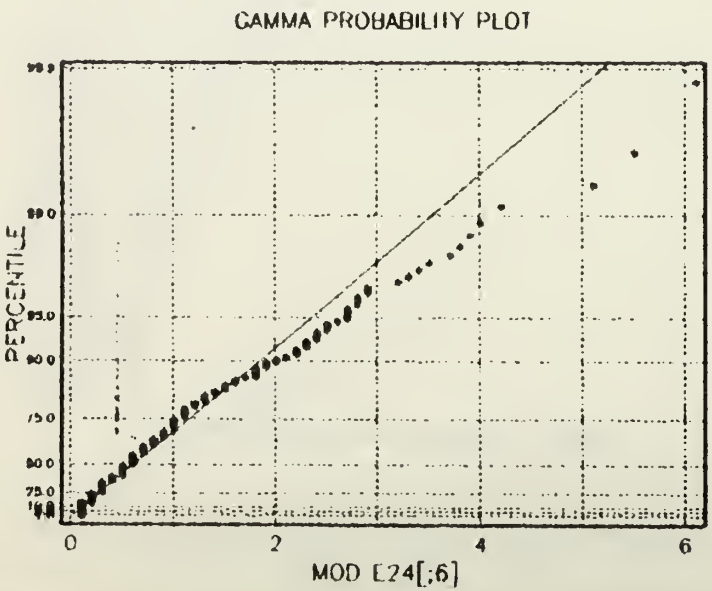
PARAMETER	ESTIMATE	LOWER	UPPER
ALPHA	1.3098	1.1995	1.54
BETA	0.0334	0.45371	0.61300

Fig. 11

24-hour Absolute Forecast Errors for X_o








```
                    GAMMA DISTRIBUTION

X           :  MOD E24[;6]
SELECTION   :  ALL
LABEL       :  MOD E24[;6]
SAMPLE SIZE:   404
MINIMUM     :     .100
MAXIMUM     :    6.100
CENSORING   :  NONE
EST. METHOD:   MAXIMUM LIKELIHOOD

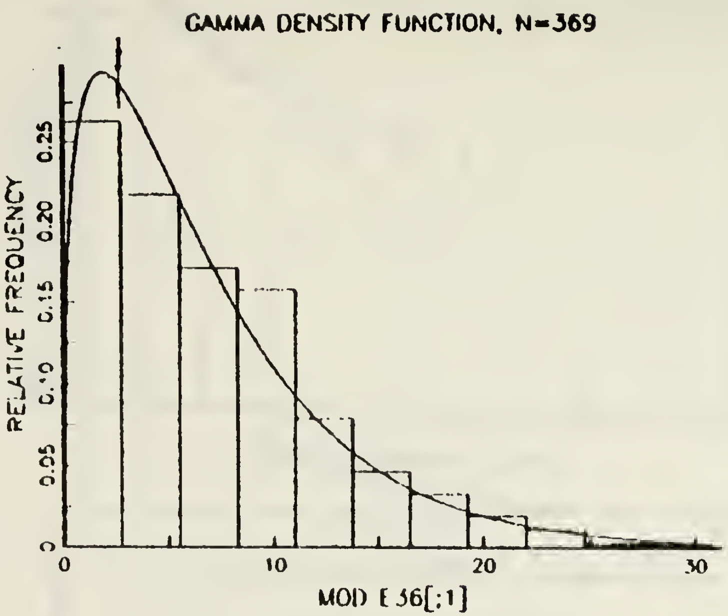
            SAMPLE     FITTED            COVARIANCE MATRIX OF
MEAN     :  0.83317    0.83317           PARAMETER ESTIMATES
STD DEV  :  0.86053    0.76537               ALPHA       BETA
SKEWNESS:   2.3356     1.8372        ALPHA  0.0055621  -0.0033
KURTOSIS:  10.185      8.0032         BETA -0.0033      0.0029905

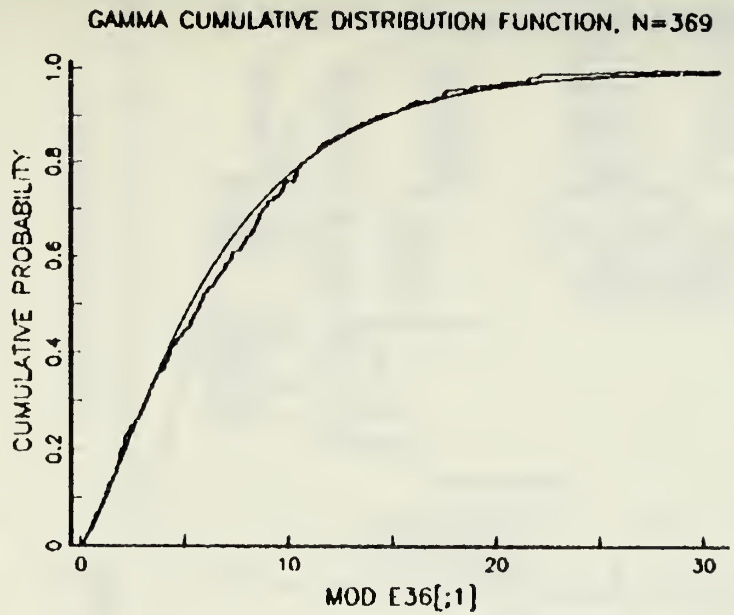
PERCENTILES SAMPLE     FITTED            GOODNESS OF FIT
     5:       0.1       0.083003         CHI-SQUARE  :   13.907
    10:       0.1       0.11708            DEG FREED.    4
    25:       0.2       0.28098            SIGNIF    :   0.0075907
    50:       0.6       0.614            KOLM-SMIRN  :   0.088948
    75:       1         1.1517             SIGNIF    :   0.0028078
    90:       2         1.8907           CRAMER-V M  :   0.30778
    95:       2.7       2.3519             SIGNIF    :  < .025
                                         ANDER-DARL  :   4.4578
                                           SIGNIF    :  < .01
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

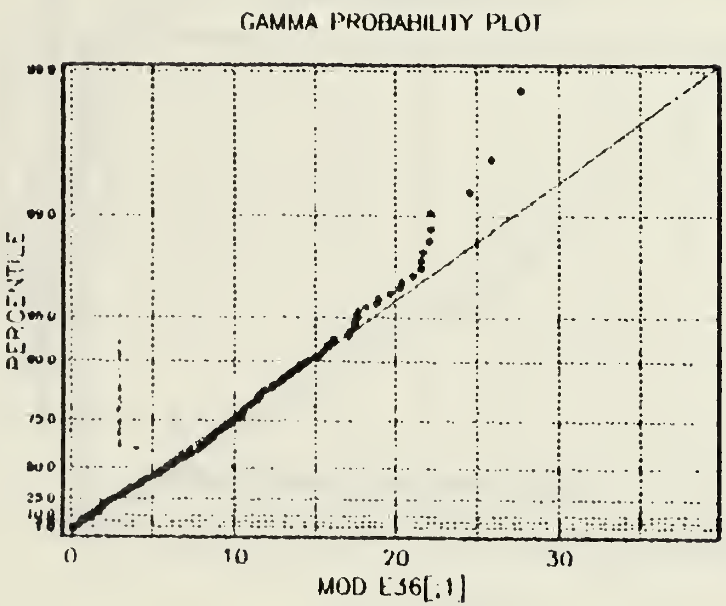
                 0.95 CONFIDENCE INTERVALS
PARAMETER    ESTIMATE   LOWER     UPPER
ALPHA         1.185     1.0388    1.3312
 BETA         0.70308   0.59508   0.81028
```

Fig. 12

24-hour Absolute Forecast Errors for Y_0







GAMMA DISTRIBUTION

X	:	MOD E36[;1]
SELECTION	:	ALL
LABEL	:	MOD E36[;1]
SAMPLE SIZE	:	369
MINIMUM	:	.100
MAXIMUM	:	27.000
CENSORING	:	NONE
EST. METHOD	:	MAXIMUM LIKELIHOOD

	SAMPLE	FITTED
MEAN :	6.001	6.001
STD DEV :	5.3725	5.0836
SKEWNESS :	1.0765	1.7047
KURTOSIS :	3.8433	7.3567

COVARIANCE MATRIX OF PARAMETER ESTIMATES

	ALPHA	BETA
ALPHA	0.0084331	-0.030504
BETA	-0.030504	0.16012

PERCENTILES	SAMPLE	FITTED
5	0.6	0.69651
10	1.1	1.2009
25	2.8	2.8108
50	5.7	5.3059
75	9.0	9.4600
90	14.6	14.647
95	17.8	18.447

GOODNESS OF FIT

CHI-SQUARE	:	8.0081
DEG FREED	:	7
SIGNIF	:	0.10029
KOLM-SMIRN	:	0.050016
SIGNIF	:	0.31443
CRAMER-V M	:	0.1084
SIGNIF	:	> .15
ANDER DARL	:	0.69944
SIGNIF	:	> .15

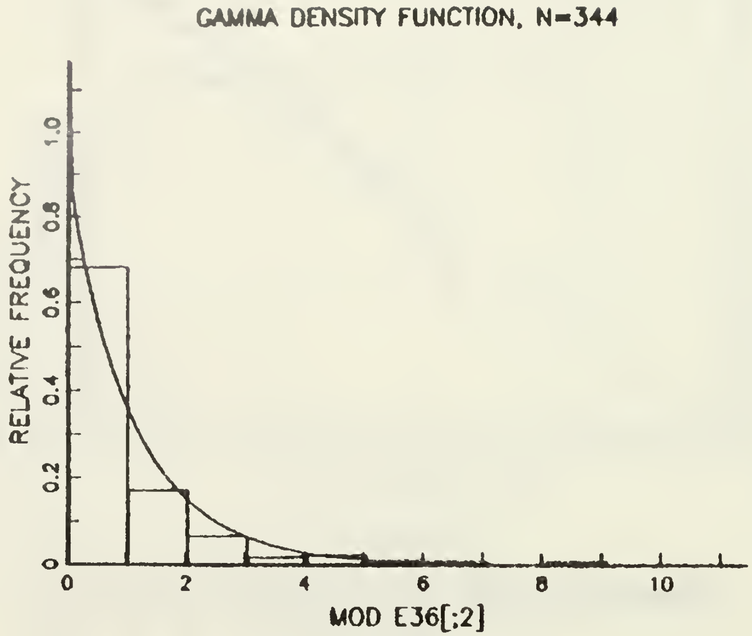
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

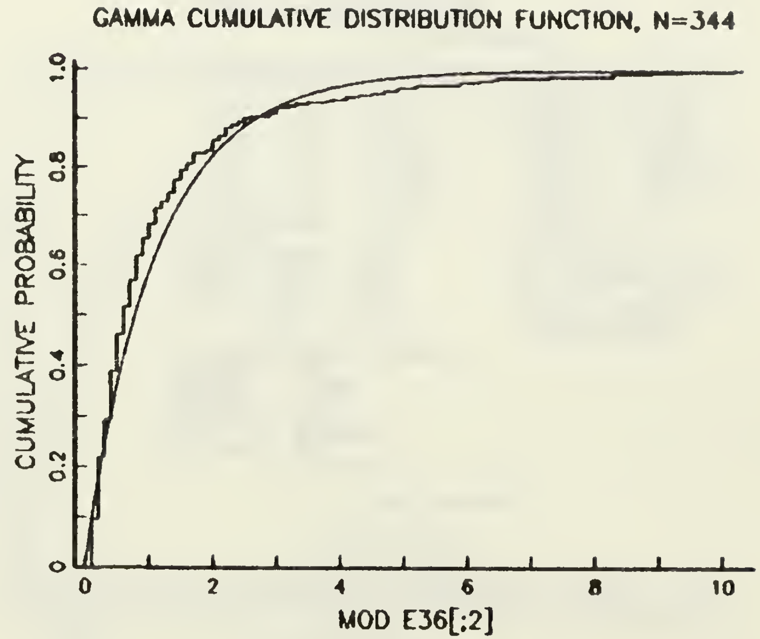
0.95 CONFIDENCE INTERVALS

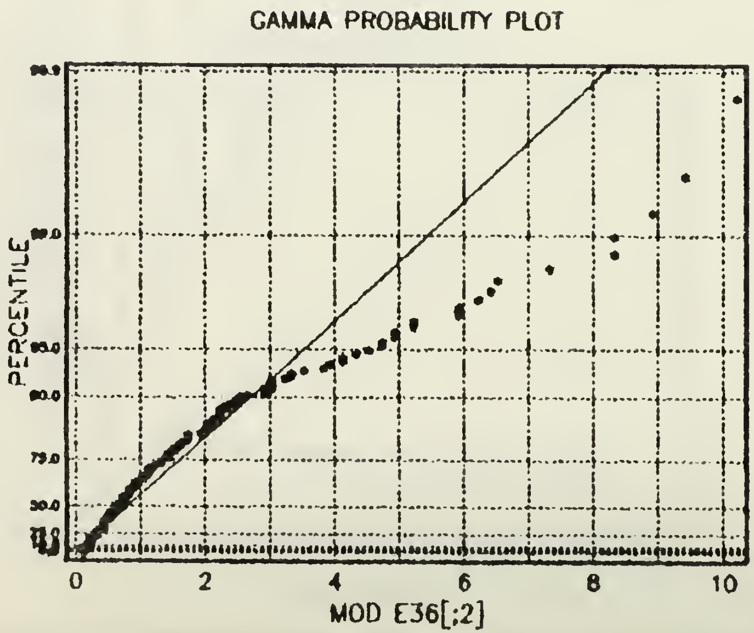
PARAMETER	ESTIMATE	LOWER	UPPER
ALPHA	1.3772	1.1972	1.5672
BETA	4.9964	4.2119	5.7808

Fig. 13

36-hour Absolute Forecast Errors for A







GAMMA DISTRIBUTION

X : MOD E36[;2]
SELECTION : ALL
LABEL : MOD E36[;2]
SAMPLE SIZE: 344
MINIMUM : .100
MAXIMUM : 10.200
CENSORING : NONE
EST. METHOD: MAXIMUM LIKELIHOOD

	SAMPLE	FITTED
MEAN :	1.187	1.187
STD DEV :	1.8400	1.178
SKEWNESS:	3.014	2.0[illegible]
KURTOSIS:	13.[illegible]	9.[illegible]

COVARIANCE MATRIX OF PARAMETER ESTIMATES

	ALPHA	BETA
ALPHA	0.[illegible]	-0.[illegible]
BETA	-0.[illegible]	0.[illegible]

PERCENTILES	SAMPLE	FITTED
5:	0.1	0.084106
10:	0.2	0.11[illegible]
20:	0.3	0.[illegible]
50:	0.8	0.79037
75:	1.4	1.6041
90:	2.6	2.6078
95:	4.8	3.5107

GOODNESS OF FIT

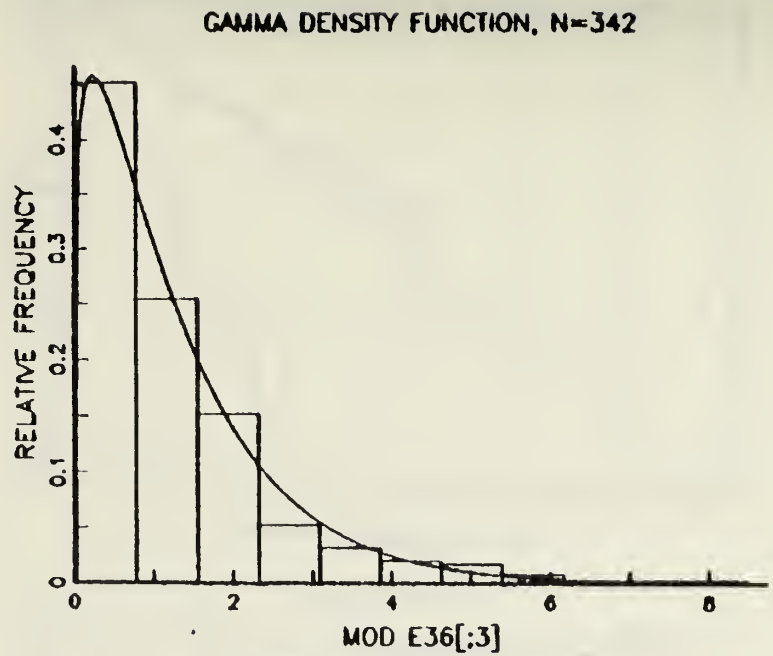
CHI-SQUARE :	24.240
DEG FREEDOM :	2
SIGNIF :	0.[illegible]
KOLM-SMIRNOV :	0.11[illegible]
SIGNIF :	0.[illegible]
CRAMER-V M :	1.176
SIGNIF :	< .01
ANDER-DARL :	7.0[illegible]
SIGNIF :	< .01

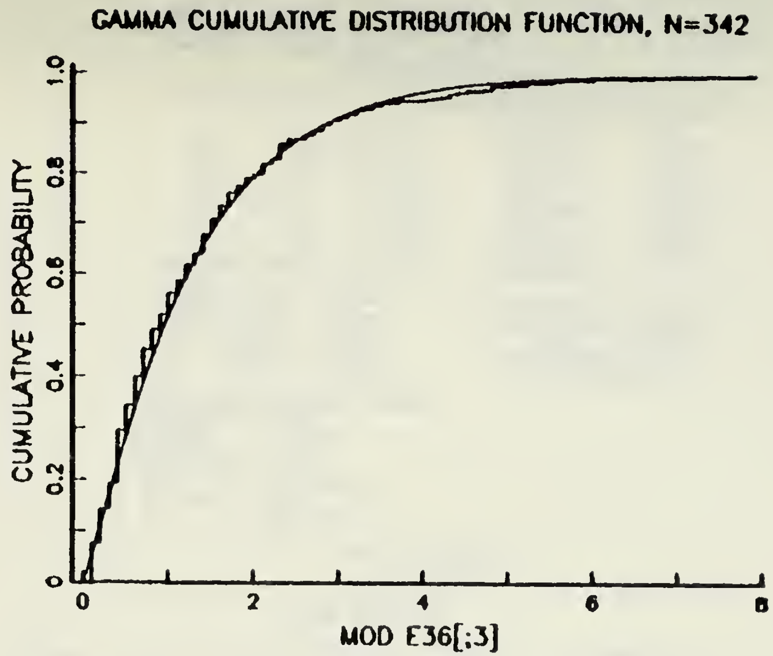
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

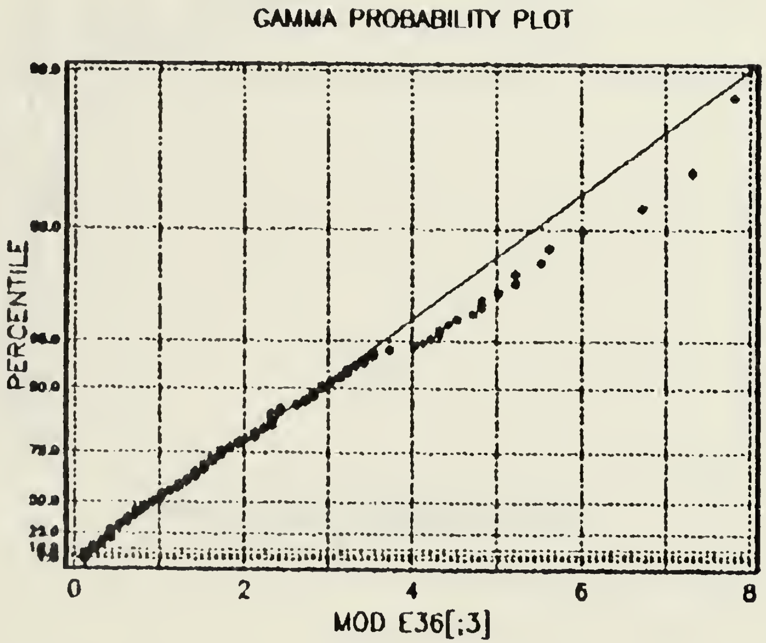
0.[illegible] CONFIDENCE INTERVALS

PARAMETER	ESTIMATE	LOWER	UPPER
ALPHA	0.[illegible]	0.[illegible]	1.0018
BETA	1.1[illegible]	0.[illegible]	1.[illegible]

Fig. 14







GAMMA DISTRIBUTION

```
X            :  MOD E36[;3]
SELECTION    :  ALL
LABEL        :  MOD E36[;3]
SAMPLE SIZE  :  342
MINIMUM      :    .100
MAXIMUM      :   7.800
CENSORING    :  NONE
EST. METHOD  :  MAXIMUM LIKELIHOOD

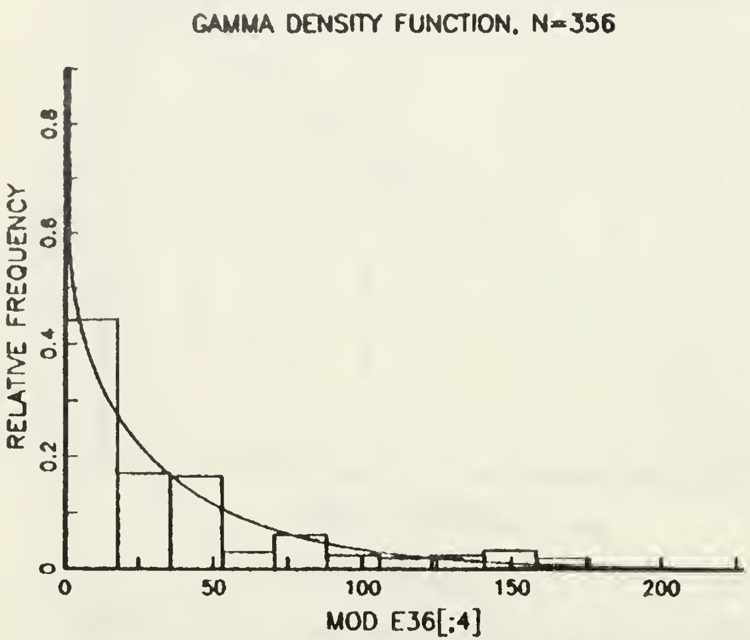
             SAMPLE     FITTED          COVARIANCE MATRIX OF
MEAN      :  1.2930     1.2930          PARAMETER ESTIMATES
STD DEV   :  1.2783     1.1771                ALPHA        BETA
SKEWNESS  :  1.9609     1.8100          ALPHA  0.0086531  -0.008074
KURTOSIS  :  7.8837     7.980           BETA  -0.008074    0.0081567

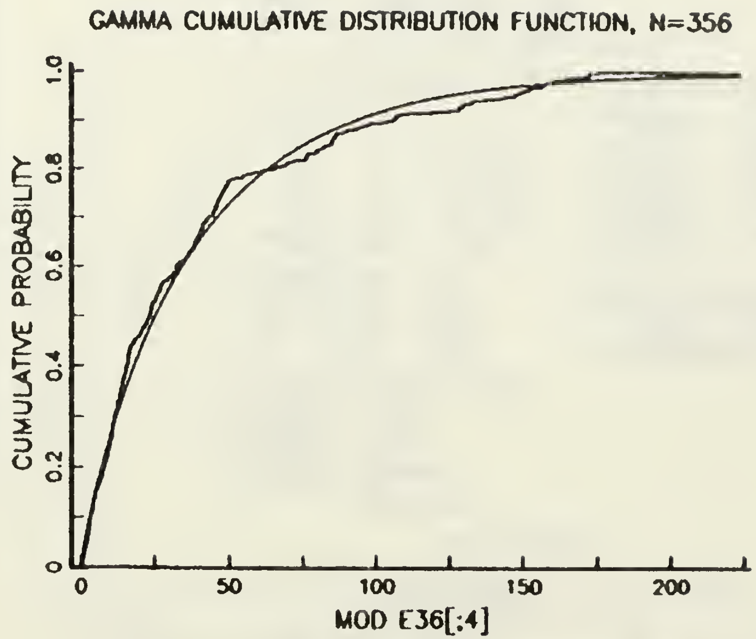
PERCENTILES  SAMPLE     FITTED          GOODNESS OF FIT
      5:      0.1       0.10182         CHI-SQUARE  :   7.8373
     10:      0.2       0.18770           DEG FREED :   5
     25:      0.4       0.44350           SIGNIF    :   0.16644
     50:      0.8       0.90603         KOLM-SMIRN  :   0.07
     75:      1.7       1.7875            SIGNIF    :   0.07005
     90:      2.9       2.8433          CRAMER-V M  :   0.23767
     95:      4.1       3.636             SIGNIF    :   > .15
                                        ANDER-DARL  :   1.6566
                                          SIGNIF    :   < .10
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

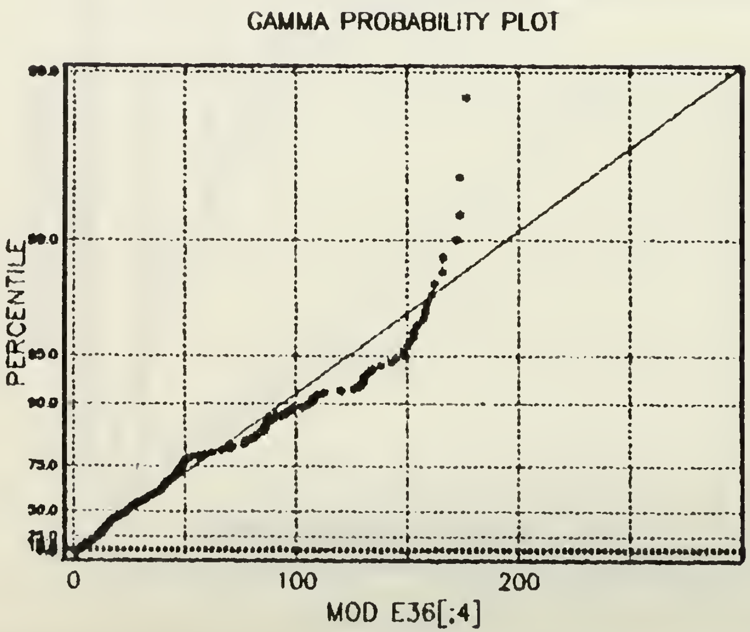
                 0.95 CONFIDENCE INTERVALS
PARAMETER   ESTIMATE   LOWER    UPPER
ALPHA        1.2062    1.0450   1.3705
 BETA        1.0708    0.8630   1.2470
```

Fig. 15

36-hour Absolute Forecast Errors for R








```
                         GAMMA DISTRIBUTION

X           :  MOD E36[:4]
SELECTION   :  ALL
LABEL       :  MOD E36[:4]
SAMPLE SIZE:   356
MINIMUM     :    .100
MAXIMUM     :   175.000
CENSORING   :  NONE
EST. METHOD:   MAXIMUM LIKELIHOOD

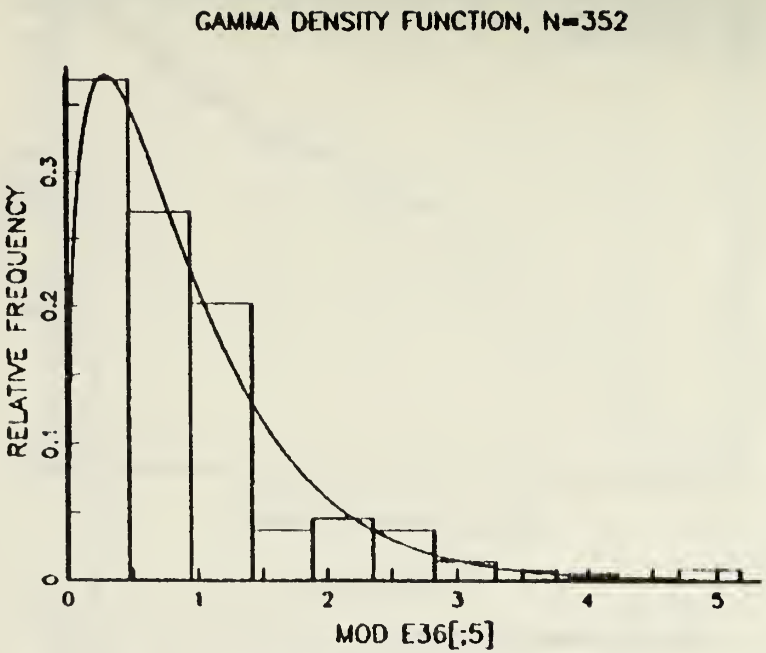
            SAMPLE      FITTED              COVARIANCE MATRIX OF
MEAN      : 38.83       38.83               PARAMETER ESTIMATES
STD DEV   : 42.382      41.920                   ALPHA        BETA
SKEWNESS:    1.671       2.1504           ALPHA  0.0031208   -0.10408
KURTOSIS:    4.0821      9.0048            BETA -0.10408     15.402

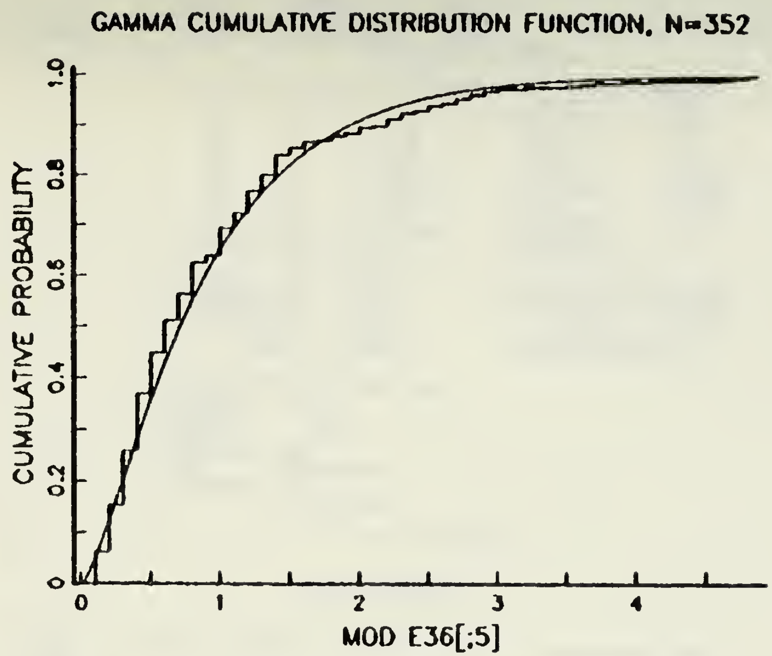
PERCENTILES SAMPLE      FITTED              GOODNESS OF FIT
      5:           1.0       1.3193         CHI-SQUARE  :     4.101121
     10:           2.0       3.0121           DEG FREED:      7.000000
     25:           8.7       8.4345           SIGNIF    :     1.4110E-0
     50:          23        25.184          KOLM-SMIRN  :     6.2100E-2
     75:          47.8      53.770            SIGNIF    :     1.2703E-1
     90:         100.0      92.837          CRAMER-V M  :     2.1120E-1
     95:         147.5     122.85             SIGNIF    :   > .15
                                            ANDER-DARL  :     1.332000
                                              SIGNIF    :   > .15
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

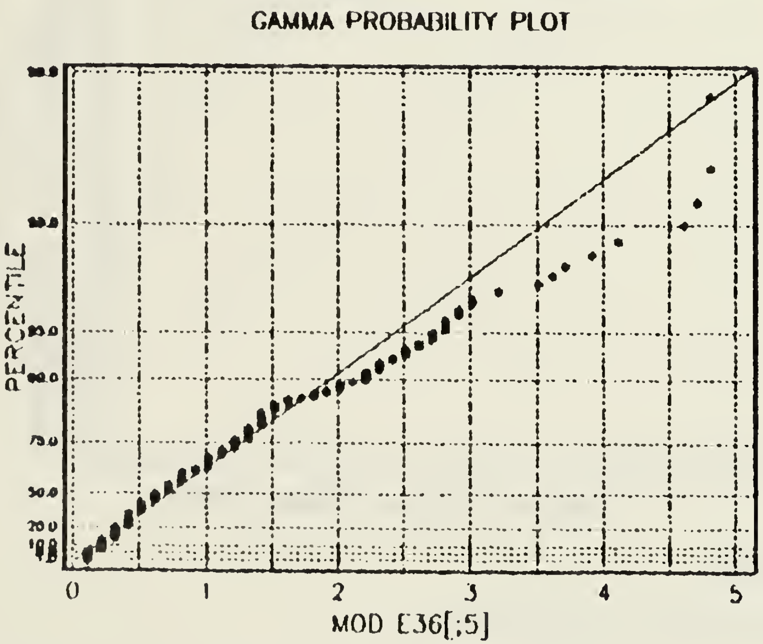
                       0.95 CONFIDENCE INTERVALS
PARAMETER    ESTIMATE    LOWER     UPPER
ALPHA          0.85770   0.74827   0.96720
 BETA         45.200    37.878    52.082
```

Fig. 16

36-hour Absolute Forecast Errors for α







GAMMA DISTRIBUTION

X : MOD E36[;5]
SELECTION : ALL
LABEL : MOD E36[;5]
SAMPLE SIZE: 352
MINIMUM : .100
MAXIMUM : 4.800
CENSORING : NONE
EST. METHOD: MAXIMUM LIKELIHOOD

	SAMPLE	FITTED
MEAN :	0.91847	0.91847
STD DEV :	0.83815	0.76130
SKEWNESS:	1.8658	1.659
KURTOSIS:	7.6338	7.1233

COVARIANCE MATRIX OF PARAMETER ESTIMATES

	ALPHA	BETA
ALPHA	0.0088437	-0.0043132
BETA	-0.0043132	0.0026467

PERCENTILES	SAMPLE	FITTED
5:	0.1	0.10234
10:	0.2	0.17722
25:	0.3	0.38347
50:	0.8	0.71878
75:	1.2	1.2507
90:	2.1	1.9281
95:	2.7	2.4171

GOODNESS OF FIT
CHI-SQUARE : 18.881
DEG FREED: 5
SIGNIF : 0.0027848
KOLM-SMIRN : 0.060381
SIGNIF : 0.0033187
CRAMER-V M : 0.81113
SIGNIF : < .00
ANDER-DARL : 3.1577
SIGNIF : < .025

KS. AD. AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS

0.95 CONFIDENCE INTERVALS

PARAMETER	ESTIMATE	LOWER	UPPER
ALPHA	1.4531	1.2507	1.6556
BETA	0.63118	0.53429	0.73208

Fig. 17

36-hour Absolute Forecast Errors for X_o

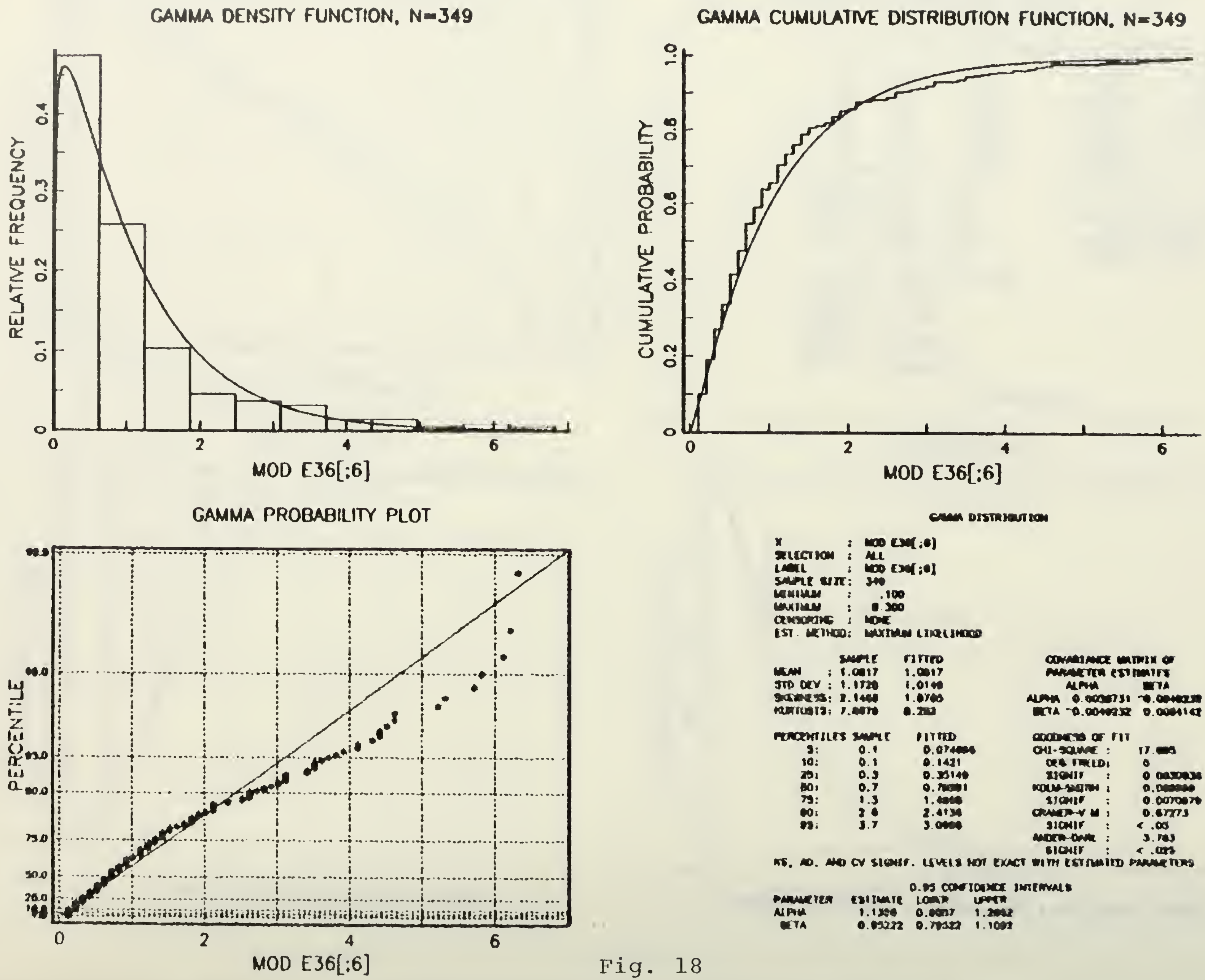

GAMMA DENSITY FUNCTION, N=349
RELATIVE FREQUENCY
0
0.1
0.2
0.3
0.4
0
2
4
6
MOD E36[;6]
GAMMA CUMULATIVE DISTRIBUTION FUNCTION, N=349
CUMULATIVE PROBABILITY
0
0.2
0.4
0.6
0.8
1.0
0
2
4
6
MOD E36[;6]
GAMMA PROBABILITY PLOT
PERCENTILE
75.0
50.0
25.0
0
2
4
6
MOD E36[;6]
GAMMA DISTRIBUTION
X : MOD E36[;6]
SELECTION : ALL
LABEL : MOD E36[;6]
SAMPLE SIZE: 349
MINIMUM : .100
MAXIMUM : [illegible]
CENSORING : NONE
EST. METHOD: MAXIMUM LIKELIHOOD
SAMPLE FITTED
MEAN : 1.0817 1.0817
STD DEV : 1.1720 1.0140
SKEWNESS: 2.1468 1.8786
KURTOSIS: 7.8070 8.[illegible]
COVARIANCE MATRIX OF
PARAMETER ESTIMATES
ALPHA BETA
ALPHA 0.0038731 -0.0040232
BETA -0.0040232 0.0064142
PERCENTILES SAMPLE FITTED
5: 0.1 0.074[illegible]
10: 0.1 0.1421
25: 0.3 0.35140
50: 0.7 0.7[illegible]
75: 1.3 1.4[illegible]
90: 2.6 2.4136
95: 3.7 3.0[illegible]
GOODNESS OF FIT
CHI-SQUARE : 17.[illegible]
DEG FREED: 6
SIGNIF : 0.00[illegible]
KOLM-SMITH : 0.0[illegible]
SIGNIF : 0.0070[illegible]
CRAMER-V M : 0.67273
SIGNIF : < .05
ANDER-DARL : 3.783
SIGNIF : < .025
KS, AD, AND CV SIGNIF. LEVELS NOT EXACT WITH ESTIMATED PARAMETERS
0.95 CONFIDENCE INTERVALS
PARAMETER ESTIMATE LOWER UPPER
ALPHA 1.1[illegible] 0.[illegible] 1.2[illegible]
BETA 0.95222 0.79322 1.1092

Fig. 18

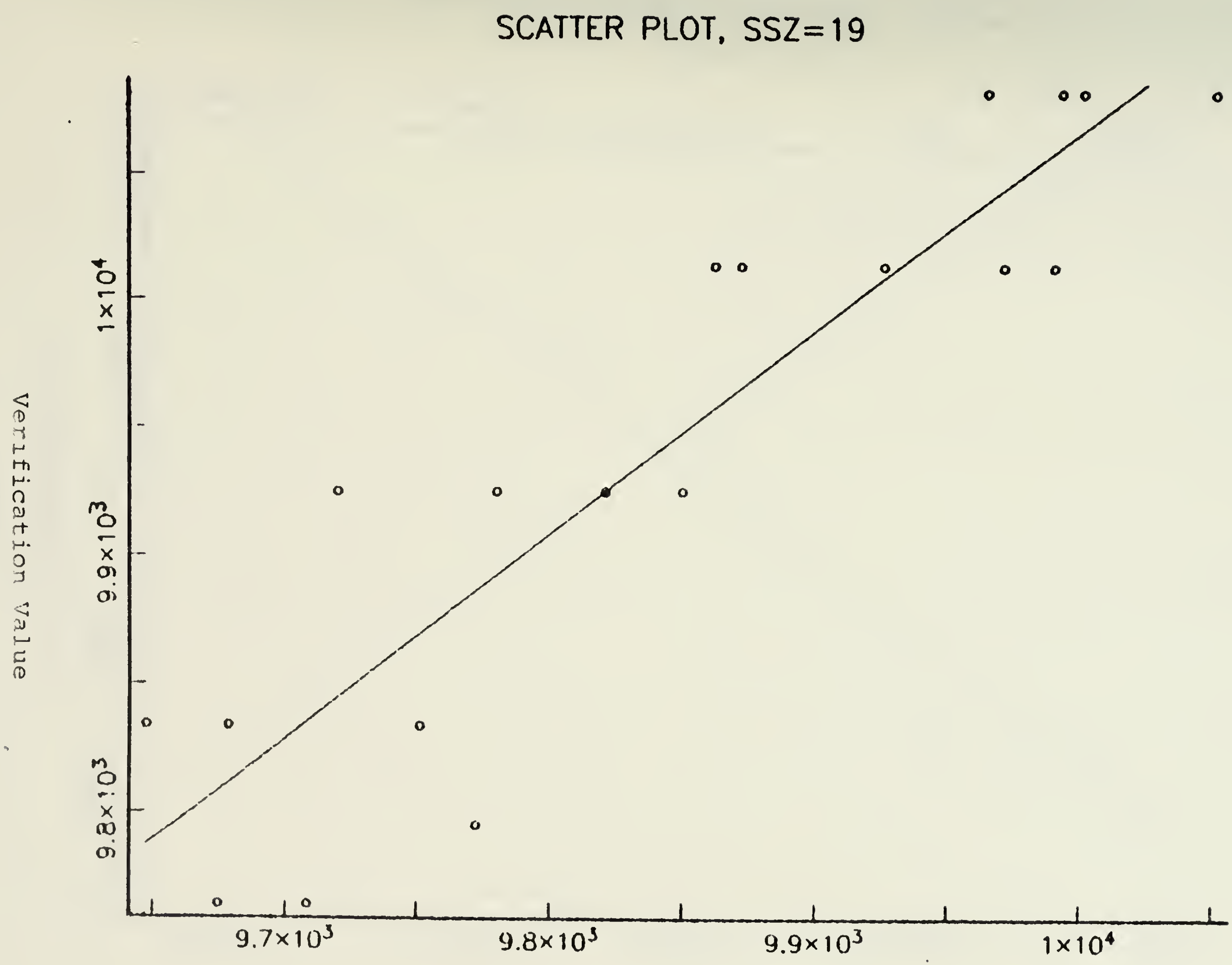


FIGURE 19

FORECASTED VALUES OF AMPLITUDE - STORM 2

$R^2 = .558$

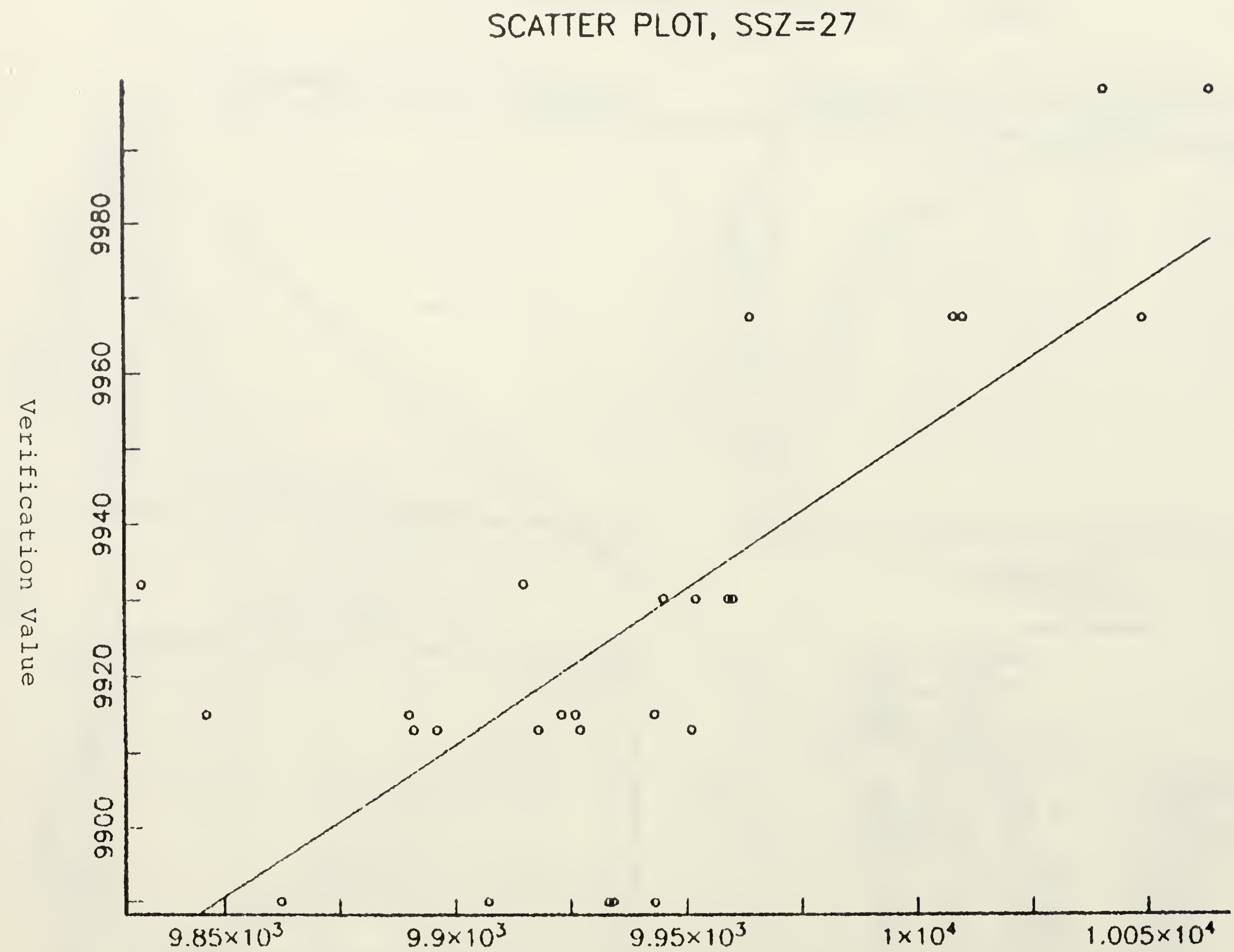


FIGURE 20

FORECASTED VALUES OF AMPLITUDE - STORM 10

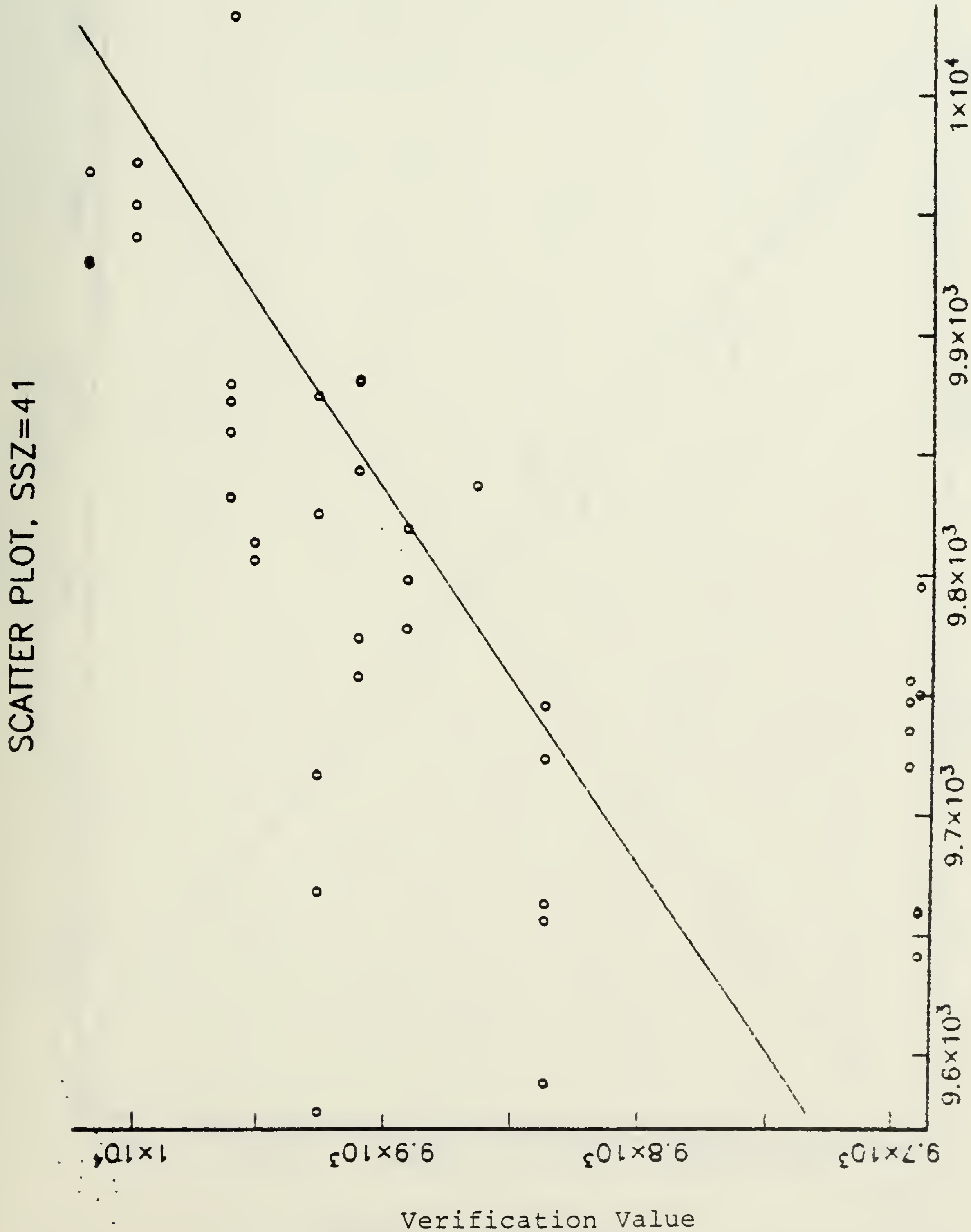


FIGURE 21

FORECASTED VALUES OF AMPLITUDE - STORM 11

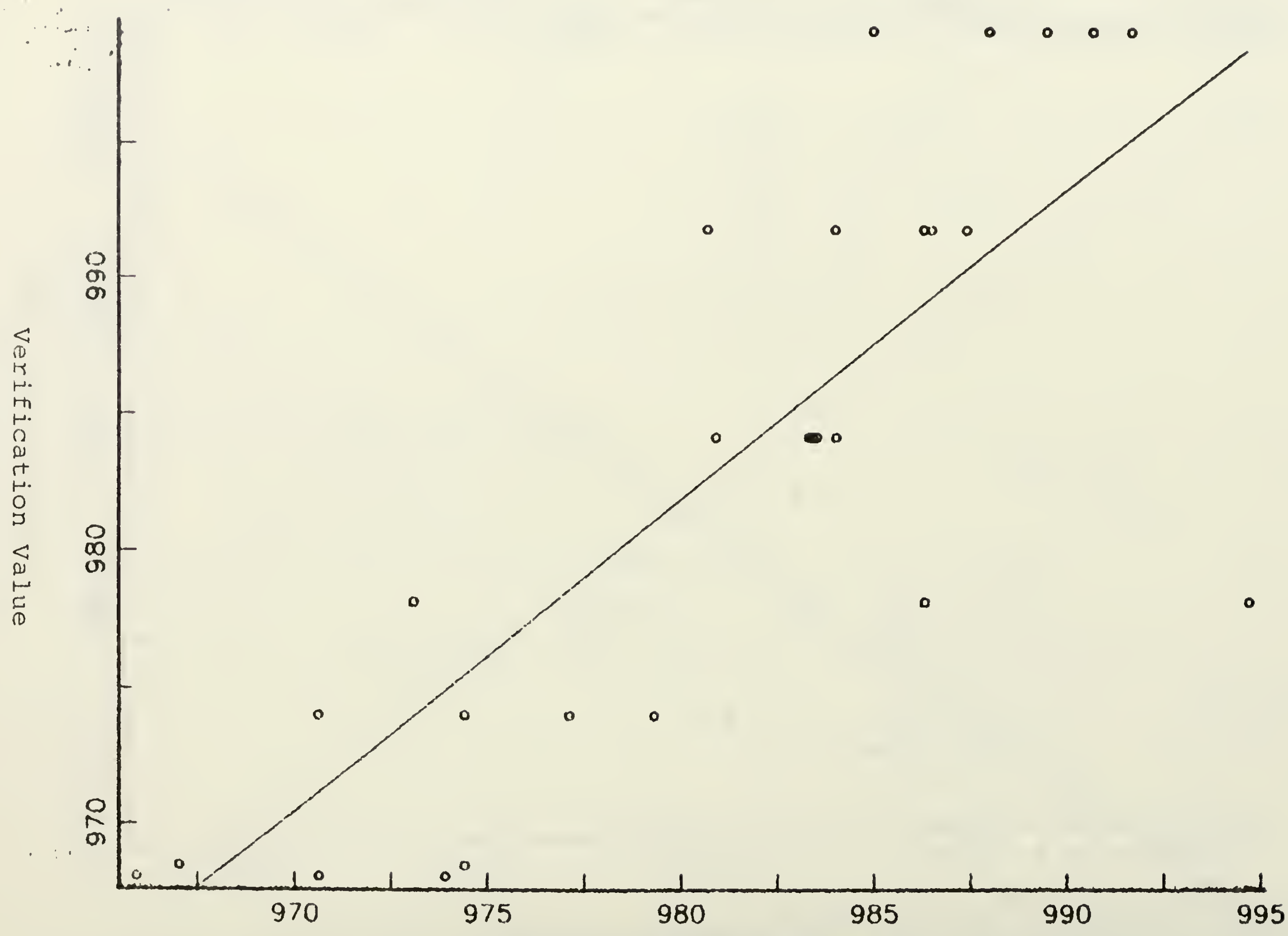


FIGURE 22

FORECASTED VALUES OF AMPLITUDE - STORM 20

SCATTER PLOT, SSZ=34

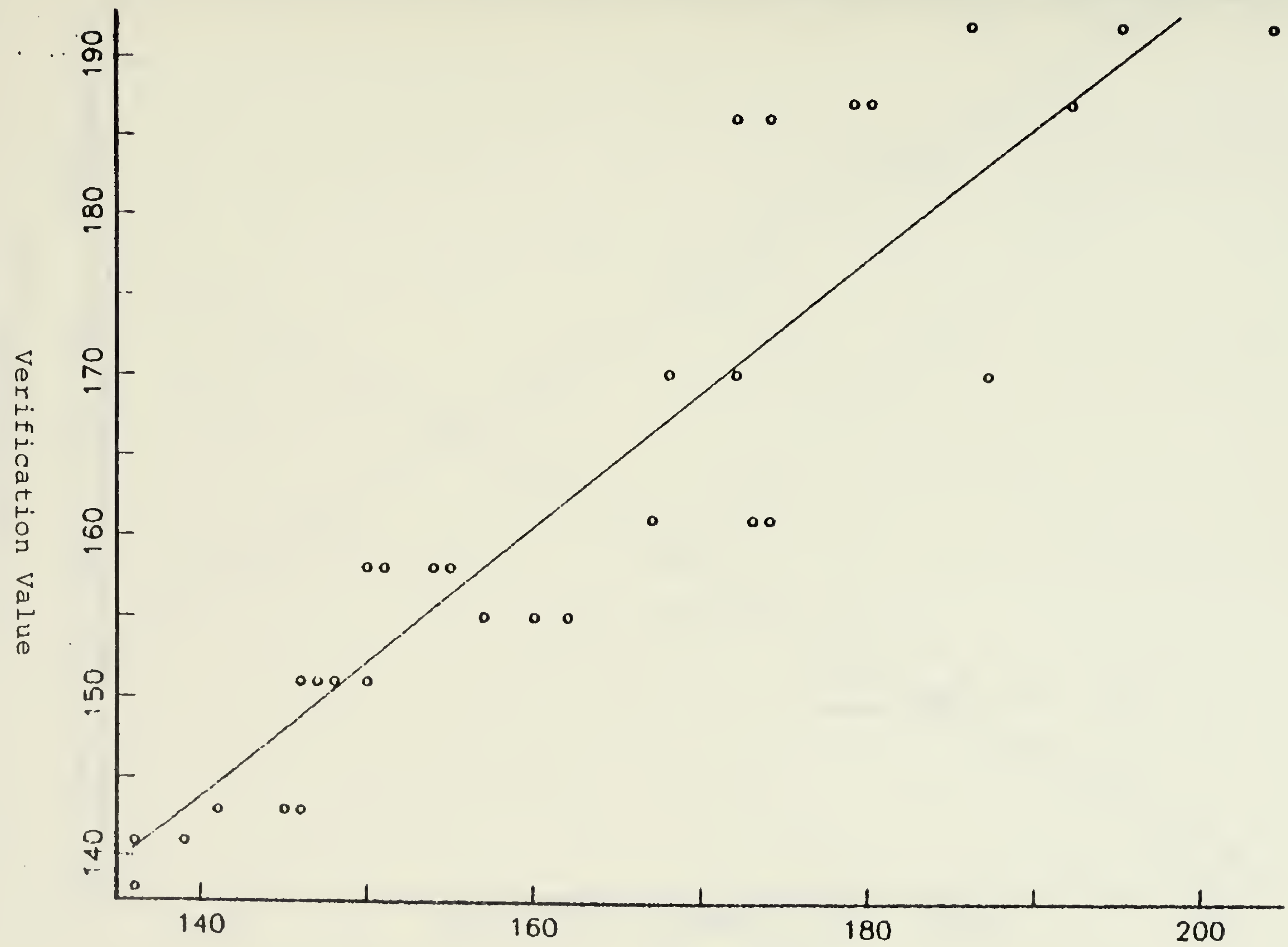


FIGURE 23

FORECASTED VALUE OF X_O - STORM 4

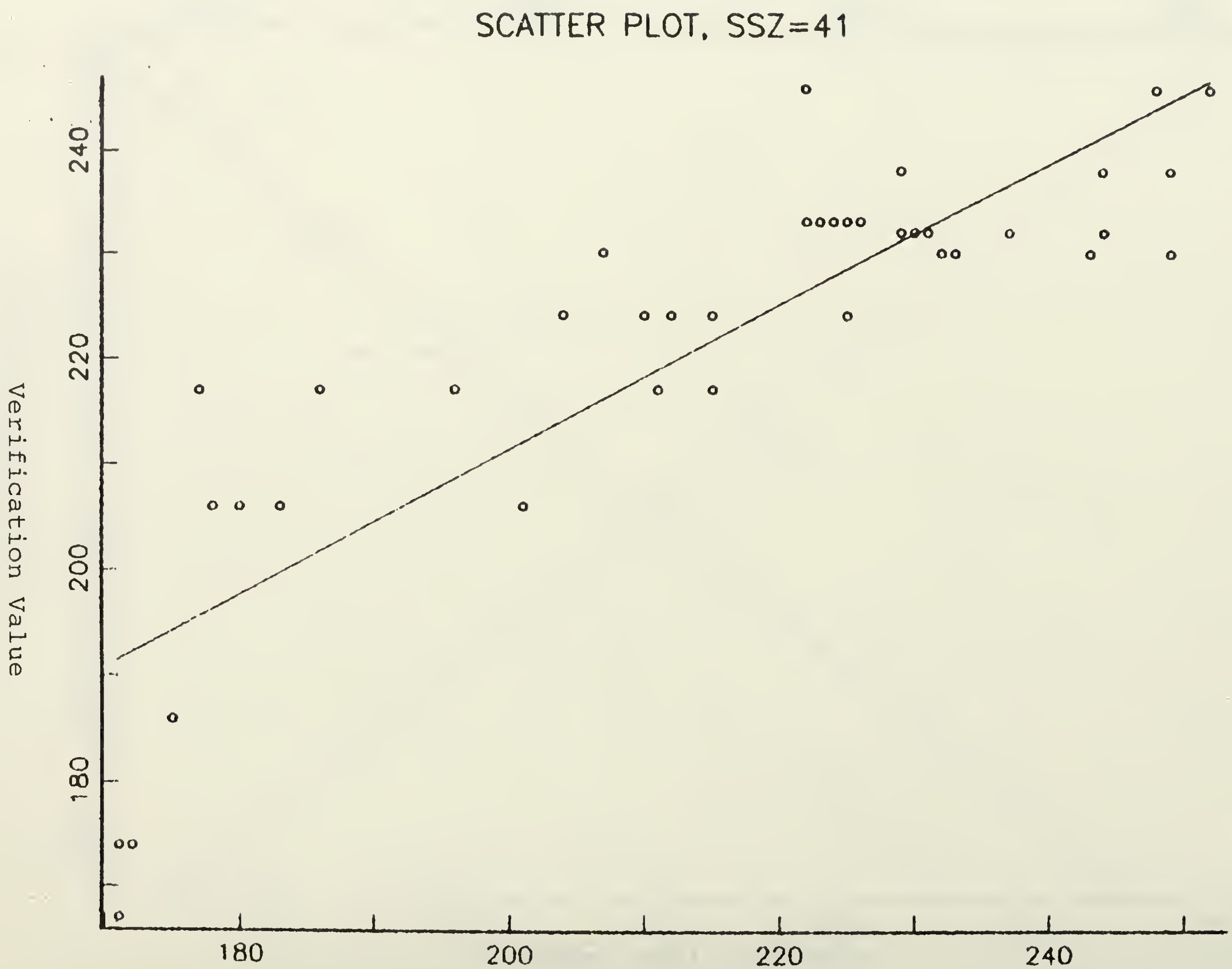


FIGURE 24

FORECASTED VALUE OF X_o - STORM 11

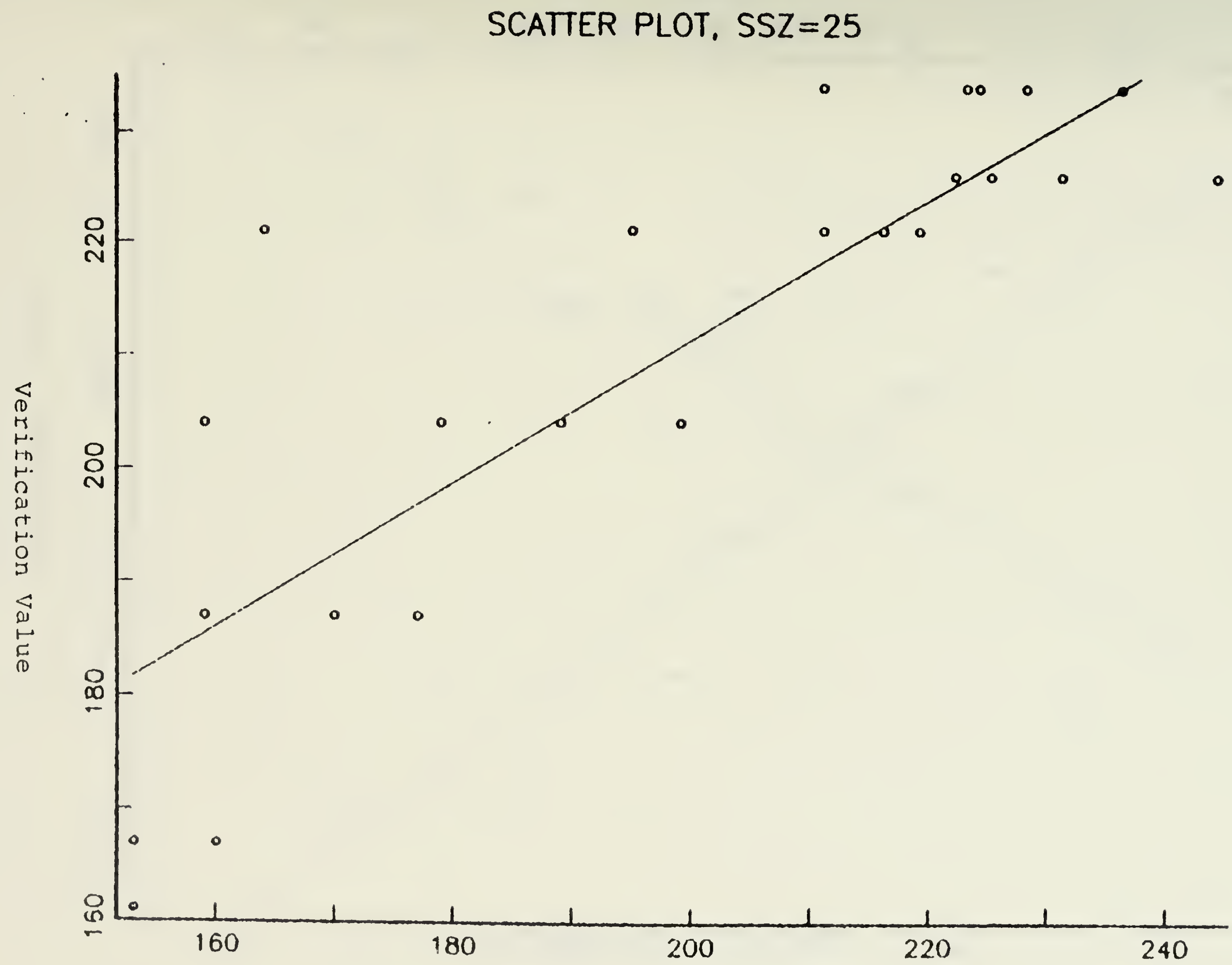


FIGURE 25

FORECASTED VALUE OF X_o - STORM 12

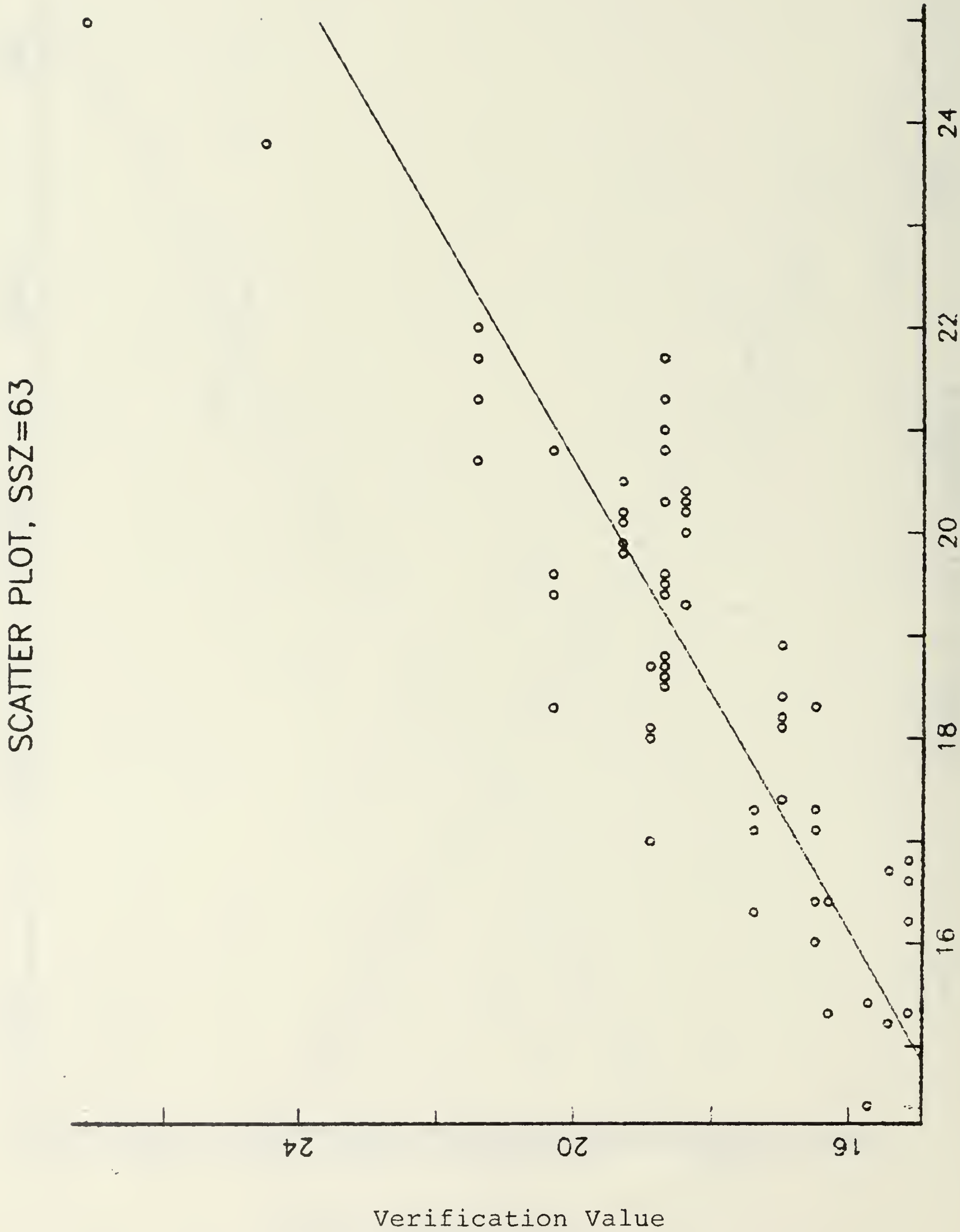


FIGURE 26

FORECASTED VALUE OF X_O - STORM 16

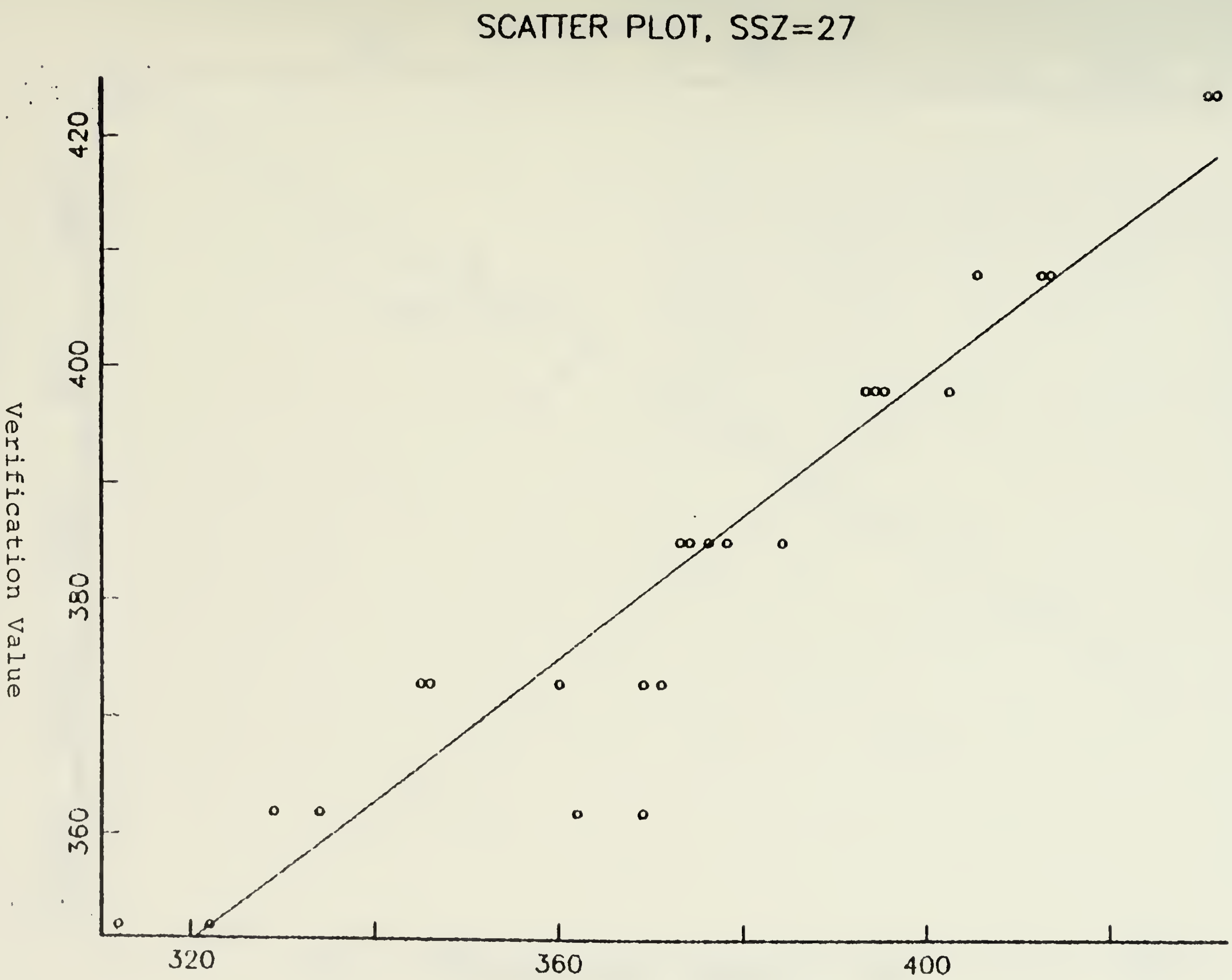


FIGURE 27

FORECASTED VALUES OF Y_O - STORM 10

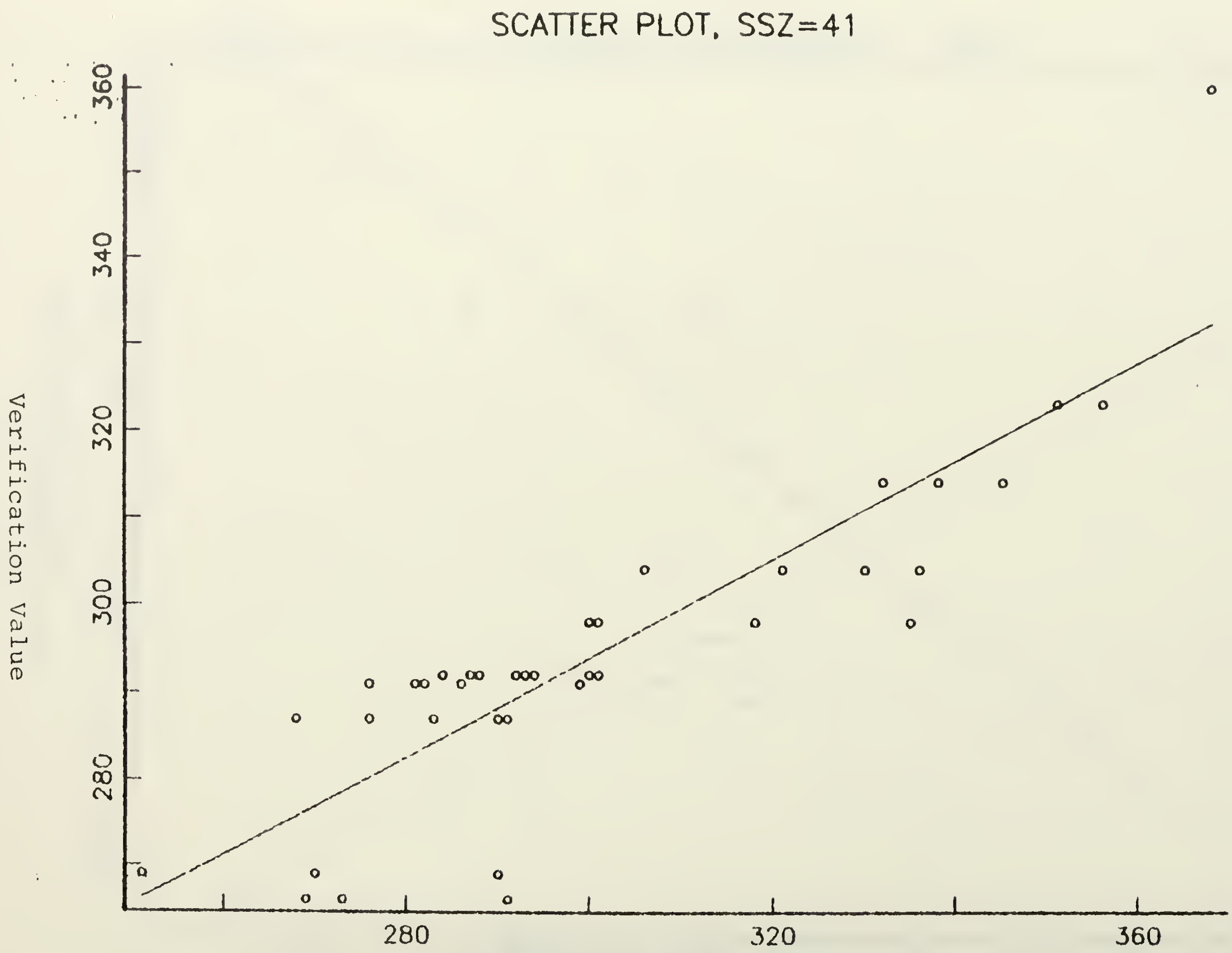


FIGURE 28

FORECASTED VALUES OF Y_O - STORM 11

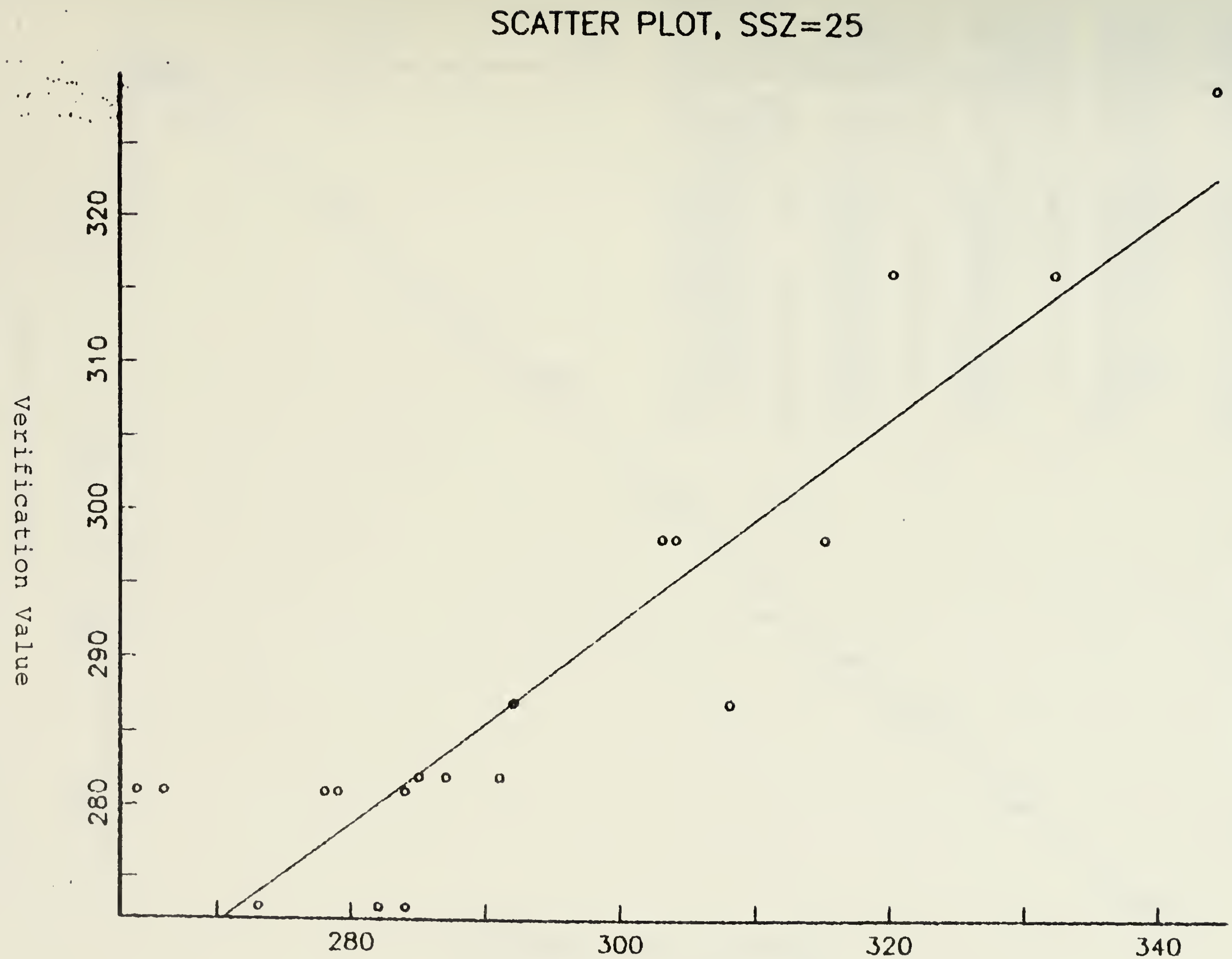


FIGURE 29

FORECASTED VALUES OF Y_O - STORM 12

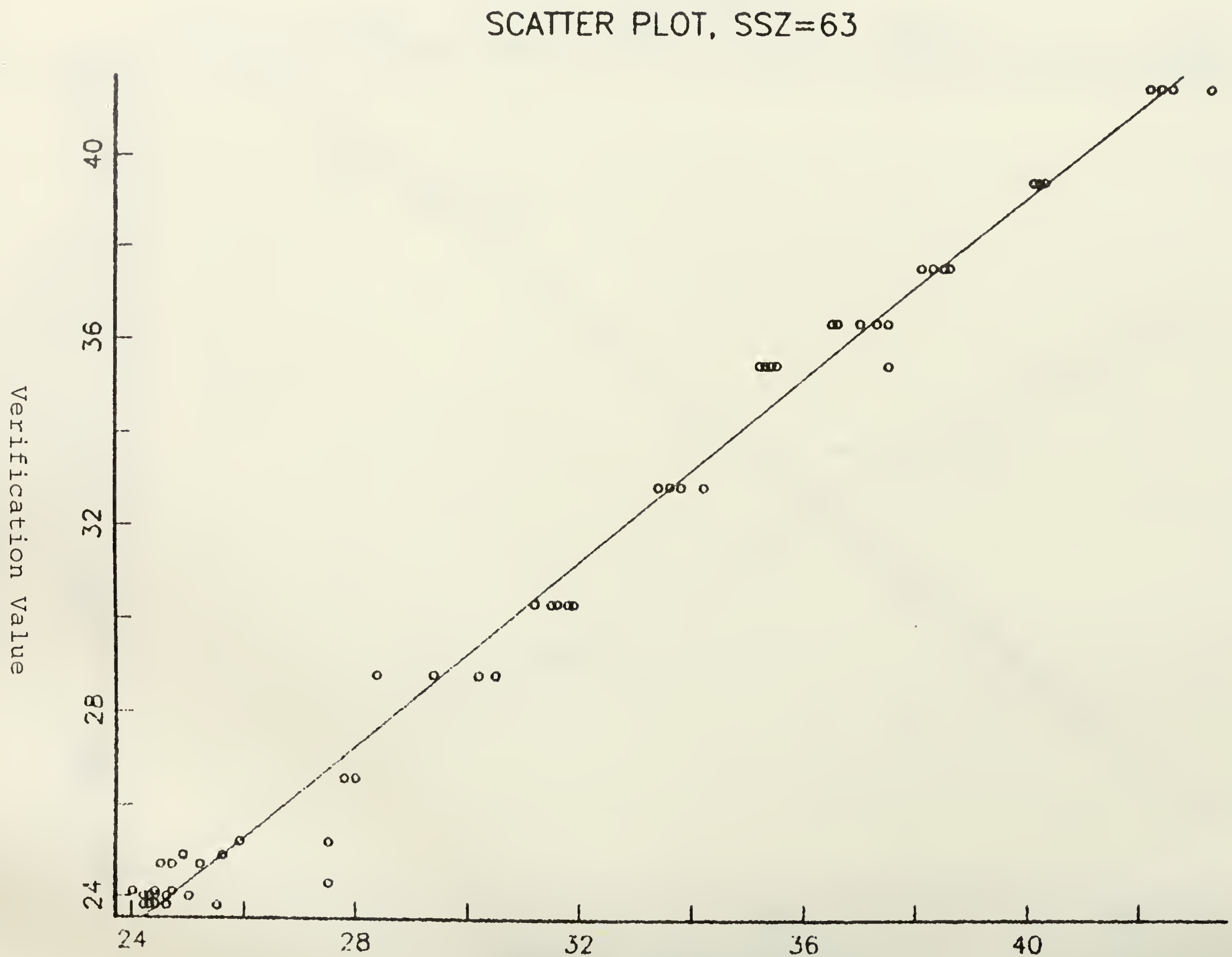


FIGURE 30

FORECASTED VALUES OF Y_O - STORM 16

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